ASSOCIATIONS OF FOOD INSECURITY, SOCIOECONOMIC STATUS, AND TYPE 2 DIABETES AMONG MEXICAN AMERICANS AND NON-HISPANIC WHITES IN THE UNITED STATES

BY SEO YEON JANG

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ABSTRACT OF THE THESIS

Associations of food insecurity, socioeconomic status, and type 2 diabetes among Mexican Americans and non-Hispanic Whites in the United States

by SEO YEON JANG

Thesis Director:

Nurgül Fitzgerald, Ph.D., R.D.

Mexican Americans are the largest segment of Hispanics in the United States of America (U.S.). Hispanics and Mexican Americans are more likely to have higher rates of type 2 diabetes (T2D) and its risk factors such as obesity, physical inactivity, low socioeconomic status (SES), and food insecurity compared to non-Hispanic Whites (NHW). However, the research looking into the associations between these risk factors and T2D, and the potential racial/ethnic differences is limited. This study examined whether food insecurity was related to T2D independently of low SES and a wide range of T2D risk factors among Mexican Americans and non-Hispanic Whites (NHW) in a nationally representative sample in the U.S. About 12,944 adults, including 2,955 Mexican Americans and 6,363 non-Hispanic Whites, 20-84yr, from the National Health and Nutrition Examination Survey (NHANES) 1999-2004 were included in the analyses. Multivariate logistic regression analyses indicated that participants with marginal or very low food security (vs. high food security) at the household level were more likely to have T2D after adjusting for education, employment, poverty, race/ethnicity, age, gender, and country of birth ($p<0.05$). Following further adjustment for obesity, lifestyle factors (physical activity, cigarette smoking, alcohol and dietary intakes), family history of diabetes, and comorbidities, participants with very low (household) food security remained more likely to have T2D (OR 1.84, CI 1.02-3.31). When the two racial/ethnic groups were examined separately, very low food security became a stronger determinant of T2D among NHWs (OR 3.53, CI 1.58-7.87), but this association was attenuated among Mexican Americans. Low SES, as determined by education and employment levels, were marginally related to higher likelihood of having T2D among Mexican Americans ($p=0.050$) but not among NHWs. These results suggest that associations of food insecurity and SES with T2D vary between Mexican American and NHW adults. This may require different approaches for prevention efforts tailored to the needs of each racial/ethnic group.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I. INTRODUCTION

Diabetes mellitus (diabetes) is a chronic disease that is characterized by high blood glucose levels due to insulin deficiency, insulin resistance, or both (1). In 2008, nearly 24 million individuals in the United States (U.S.) were estimated to have diagnosed and undiagnosed diabetes (2). Although there are various types of diabetes, type 2 diabetes (T2D) constitutes about 90 to 95% of diabetes cases (3).

T2D has many modifiable and nonmodifiable risk factors. Genetic susceptibility (4-6), aging (7), and being from certain racial/ethnic backgrounds (e.g., Hispanics, non-Hispanic blacks, American Natives, Native Hawaiians, or Asian/Pacific Islanders) (8, 9) are the major non-modifiable risk factors. Among the racial/ethnic groups in the U.S., Hispanics are the largest and fastest-growing ethnic minority (10), and they are reported to have higher age-adjusted rates of diagnosed diabetes compared to non-Hispanic Whites (10.4% vs. 6.6% in 2004-2006, respectively) (11). Mexican Americans represent the largest segment among Hispanics in the U.S. (65.5%) (12), and they also have substantially higher age-adjusted rates of diagnosed diabetes compared to non-Hispanics whites (11.9% vs. 6.6% in 2004-2006, respectively) (11).

In addition to these genetic and racial/ethnic factors, several modifiable factors influence T2D etiology. Obesity (13) and lifestyle factors, such as physical inactivity (14-17), cigarette smoking (18, 19), alcohol (20, 21), and dietary intake patterns (22-25), have been reported to be related to T2D prevalence or incidence. In addition to having a higher prevalence of T2D, Mexican Americans are reported to have higher rates of obesity and physical inactivity, and lower rates of cigarette smoking (7).

Low socioeconomic status (SES) is another modifiable T2D risk factor. Low SES, as measured by income, education, or occupational status, appears to be positively related to the prevalence of diabetes (7, 26, 27). Further, the T2D risk factors, such as cigarette smoking (28, 29), obesity (30) and diets high in calories and fat (31), are more common among people with low SES. Similar to the other T2D risk factors, low SES is more prevalent among Mexican Americans compared to non-Hispanic Whites(7). According to the national estimates, Hispanics are more likely to be impoverished (21.8% vs. 8.3%, respectively; in 2005) (32), and they are less likely to have a college degree (13% vs. 32%, respectively; in 2007) (33) compared to non-Hispanic Whites.

Food insecurity, which can be defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (34), is closely related to SES (31, 35-38). Limited research suggests that it is also positively associated with T2D prevalence (37, 38). In 2007, 11.1% of American households were food insecure (39), and considering that T2D rates continue to increase, a potential association between T2D and food insecurity is likely to constitute a significant nutrition and health problem especially among minorities such as Mexican Americans, who are already at increased risk for T2D.

Current literature examining the associations between food insecurity and T2D (37, 38) has many limitations. First of all, it is not clear whether food insecurity and various SES indicators, such as education, poverty level, employment status, or health care coverage, are independently related to T2D prevalence. In particular, it is not known whether these associations are independent of lifestyle factors (alcohol intake, cigarette smoking, and dietary intake patterns) or comorbidities (e.g., angina pectoris, heart attack, or stroke) that may influence lifestyle behaviors. It is also not known whether these associations are independent of cultural characteristics. Acculturation, which can be defined as the process of adopting attitudes, values, and behaviors of the surrounding culture (40), has been reported to be related to diabetes (41, 42), food insecurity (31), obesity (43-45), physical inactivity (46, 47), and dietary intake patterns (31, 48-55) among Mexican Americans and other Hispanics.

Although studies have shown that Mexican Americans have higher rates of diabetes and risk factors, such as obesity, physical inactivity, and low SES, the associations between T2D, food insecurity, and other T2D risk factors among Mexican Americans versus non-Hispanic Whites have not been well-studied. Therefore, the current study was conducted to examine whether food insecurity is related to T2D independently of SES indicators (i.e., education, poverty income ratio (PIR), employment status, health care coverage), after adjusting for obesity, lifestyle, demographic factors, acculturation, and other likely confounders, among Mexican Americans and non-Hispanic Whites in the U.S. This study also sought to examine if these associations differed between Mexican Americans and non-Hispanic Whites in a nationally representative sample from the National Health and Nutrition Examination Survey (NHANES) 1999-2004.

CHAPTER II. LITERATURE REVIEW

This chapter will provide an overview of T2D and factors that are related to T2D risk including genetic susceptibility, obesity, lifestyle (physical inactivity, cigarette smoking, alcohol and dietary intake), demographic factors (racial/ethnic background, age, gender, marital status), and acculturation. Food insecurity, SES, and their documented associations with T2D and its risk factors particularly among Hispanic and Mexican Americans will be discussed in further detail. The literature search was performed by using PubMed and Google Scholar databases. The search terms used included diabetes, diabetes risk factors, food insecurity, obesity, socioeconomic factors, acculturation, and Mexican Americans.

2.1 Type 2 Diabetes

Diabetes mellitus is a chronic disease that affects almost 24 million people in the U.S. (2), and it is one of the ten leading causes of death (11). The direct and indirect costs of treating diabetes mellitus were $174 billion in 2007, and they continue to increase every year (1).

There are other forms of diabetes mellitus, such as type 1 and gestational diabetes mellitus. However, T2D is the most common form of this disease constituting about 90-95% of all diabetes cases (3). T2D is a metabolic disease characterized by hyperglycemia as a main feature. Increased insulin resistance accompanied by insufficient insulin secretion are primary factors that induce hyperglycemia (1). Type 2 diabetes involves many long-term complications or comorbidities, such as cardiovascular diseases (e.g., heart disease, stroke, or hypertension), retinopathy, nephropathy, and neuropathy (11). Such complications significantly increase the morbidity and mortality rates among people with diabetes (56).

Although T2D has a genetic origin, many other modifiable factors increase the risk for this disease. The following sections will provide an overview of some of these risk factors and the likely underlying mechanisms of their actions.

2.2 Type 2 Diabetes Risk Factors

2.2.1 Genetic Background

Genetic factors play an important role in determining the risk of developing diabetes. The majority of T2D cases is heterogeneous and involves complex gene-gene and gene-environment interactions. Genes such as peroxisome proliferator-activated receptor-g (PPAR-g), hepatocyte nuclear factor-4a (HNF-4a), HNF-1a, insulin promoter factor-1 (IPF-1), neurogenic differentiation factor-1 (NEUROD-1), or Calpain-10 (CAPN-10) and other candidate genes have been associated with susceptibility to T2D (4, 6, 57). Although these genes are related to an increased risk of T2D, other factors such as obesity and lifestyle characteristics may determine whether one develops T2D or not either directly or through interactions with genetic factors (58).

Family history of diabetes, especially with a first-degree relative (parent and/or sibling), has been reported to be significantly related to a higher risk of T2D (59, 60). Therefore, family history of diabetes has been commonly used to partially control for genetic susceptibility to this disease when examining T2D risk factors (37, 59, 60).

2.2.2 Obesity

Obesity is one of the major modifiable risk factors for T2D. The cross-sectional data from the Behavioral Risk Factor Surveillance System in 2001 (61) indicated that both overweight and obese status were significantly related to higher rates of diabetes prevalence, regardless of gender, age, race/ethnicity, educational levels, or cigarette smoking status. Prospective data from the Nurses' Health Study and the Health Professionals Follow-up Study (13) showed that the incidence of diabetes was positively associated with body mass index (BMI) for both men and women during a 10-year (1986-1996) period. In addition to the overall obesity measured by BMI, central adiposity, often measured by waist circumference (WC) and waist to hip ratio, has also been reported to be associated with higher incidence of diabetes (62).

The literature provides several potential mechanisms that might underly the associations between obesity and diabetes. One of these potential mechanisms involves elevated free fatty acids (FFA) found among those who are obese. Visceral fat has higher rates of lipolysis than subcutaneous fat tissue because of reduced insulin suppression of lipolysis (63). It has been proposed that elevated FFAs created through lypolysis may activate protein kinase C theta (PKC-theta) that leads to a decrease in tyrosine phosphorylation of the insulin receptor substrate 1 (IRS-1) in the muscle tissue. This, in turn, may reduce GLUT-4 glucose transporter activity by inhibiting insulin-induced phosphatidylinositol 3-kinase (PI 3-kinase) function. As a result, reduced GLUT-4 activity may lead to impaired insulin-induced muscle glucose uptake and muscle glycogen synthesis (64, 65). Elevated FFAs may also impair insulin suppression of hepatic glycogenolysis and gluconeogenesis, which is related to an increase in endogenous glucose production and may exacerbate insulin resistance (64, 65).

Elevated FFAs may also induce decreased skeletal muscle fatty acid oxidation and lead to excess accumulation of lipids in the muscle tissue (66). Increased intramuscular lipid accumulation has been shown to be negatively related to insulin sensitivity (67, 68).

Another mechanism for the relationship between obesity and diabetes could be through obesity-induced inflammation. Enlarged adipocytes in obesity may secrete pro-inflammatory cytokines, which may potentially induce insulin resistance (69-71). However, the underlying mechanisms are not clearly understood.

2.2.3 Lifestyle Factors

Physical activity

Higher rates of physical activity have been shown to reduce the risk of T2D. Prospective studies among U.S. female health professionals aged 45 yr and older (16) and middle-aged Finnish women and men (17) indicated that walking for about 2-3 hours per week was related to a reduced risk of diabetes independently of obesity. Gill, et al. (15) also reported in a review of 20 longitudinal studies among various populations that individuals with an elevated risk of diabetes (e.g., those who were obese, had impaired glucose regulation or family history of diabetes) showed the greatest reduction in T2D risk through increased physical activity (15). Another study among Hispanic women also showed that physical activity was related to a lower risk of gestational diabetes (14).

One of the protective mechanisms of physical activity against T2D may be a corresponding reduction in obesity (72). Other potential mechanisms include reduction of inflammation, dyslipidemia, or blood pressure (72), or the improvement of insulin sensitivity (73).

<u>Cigarette smoking</u>

Cigarette smoking has been related to a higher incidence of T2D among adults in the U.S. (18). Willi, et al. (19) reported in a review 25 observational studies among various populations that both heavy (≥ 20 cigarettes per day) vs. light smokers and current vs. former smokers had a greater risk of having T2D (19).

Smoking may contribute to the development of T2D by impairing insulin sensitivity (74). Nicotine increases catecholamines, which may impair the pathways associated with insulin action and insulin synthesis (75). Nicotine may also increase the levels of FFA by elevating lipolysis through "activating a lipolytic cell surface receptor" (75), and it may promote accumulation of abdominal fat (76, 77) through impairing hypothalamic hormonal function. Smoking could also increase inflammation (78) through increased oxidative stress (75).

<u>Alcohol intake</u>

Moderate alcohol intake may be protective against T2D. In the prospective Atherosclerosis Risk in Communities Study (1990-1998), high alcohol intake (>21 drinks/week) was related to increased T2D risk among middle-aged men (21). A European prospective study among women aged 49-70 years reported a U-shaped association between alcohol consumption and T2D (20).

Moderate alcohol consumption may be protective against T2D through increasing insulin sensitivity, (79, 80). This could be due to the alcohol-induced increases in adiponectin, an adipocyte-derived protein, which is positively associated with improved insulin sensitivity (81). Furthermore, moderate alcohol intake may have anti-inflammatory effect (82), which could reduce the risk of T2D. On the contrary, heavy alcohol consumption could lead to reduced insulin secretion (83, 84). This could be because ethanol and its metabolites such as acetate may interfere with glucose utilization and reduce the rates of glucose uptake and glucose-induced insulin secretion (83, 85).

Dietary intake

Several studies showed that certain dietary intake patterns are associated with T2D prevalence and incidence. For example, lower intakes of fruits and vegetables (22), or dietary intake patterns characterized by higher consumption of fat and refined carbohydrates and lower consumption of fruits, vegetables, whole grains, fish, and poultry have been positively associated with the development of T2D (25) independently of obesity. The mechanism underlying this potential protective effect can be through the metabolic functions of micronutrients and antioxidants in fruits and vegetables. For instance, magnesium plays a key role in insulin-mediated glucose uptake. Hence, inadequate intake of magnesium may hinder insulin secretion and result in insulin resistance (86). Fruits and vegetables are also good sources of antioxidants such as flavonoids, carotenoids, and vitamins (e.g., vitamin C, and vitamin E). Such antioxidants may be protective against diabetes through reducing oxidative stress that can hinder glucose uptake by cells (87-89). Additionally, dietary fiber is mainly found in fruits, vegetables, and whole grains, and it may reduce the risk of developing T2D by delaying carbohydrate absorption and thereby reducing postprandial hyperglycemia (90, 91).

Dietary fat composition may also be related to T2D. A prospective study among male health professionals in the U.S. indicated that diets high in saturated and total fat were related to a higher risk of T2D, but this association was not independent of obesity (25). Other studies by Salmeron, et al. (92, 93) have not confirmed the relationships between saturated, monounsaturated, and total fat intakes and T2D. However, Salmeron et al. (92) reported that higher intake of polyunsaturated fatty acids was related to a lower risk of T2D, while higher intake of dietary cholesterol was related to a higher risk of T2D after controlling for obesity and other likely confounders. Animal studies have suggested that dietary $\omega-3$ and polyunsaturated fatty acids improved insulin binding to skeletal muscle cells (94) possibly by altering the composition of membrane phospholipids surrounding the insulin receptors (94, 95).

Overall, existing literature suggests that physical inactivity, cigarette smoking, and certain dietary intake patterns, such as higher consumption of fat and refined carbohydrates and lower consumption of fruits, vegetables, whole grains, fish, and poultry, are related to a higher risk of T2D, and moderate intake of alcohol may be protective against this disease.

2.2.4 Demographic Factors

Race/ethnicity is one of the most prominent demographic factors in relationship to T2D risk. National data indicate that certain racial/ethnic populations such as Hispanics, non-Hispanic Blacks, American Natives, Native Hawaiians, and Asian/Pacific Islanders have higher rates of T2D (8, 9). According to a report from the National Institute of Diabetes and Digestive and Kidney Diseases (11), Hispanics have higher age-adjusted rates of diabetes than non-Hispanic Whites (10.4% vs. 6.6% in 2004-2006, respectively). Mexican Americans, who are the largest segment of the Hispanics in the U.S., also exhibit a greater prevalence of T2D as compared to non-Hispanic Whites (11.9% vs. 6.6% in 2004-2006, respectively; age-adjusted) (11).

Furthermore, according to the national estimates from the NHANES III, Mexican Americans (vs. non-Hispanic Whites) have greater rates of T2D risk factors such as obesity (mean BMI: 28.6kg/m^2 vs. 26.3kg/m^2, respectively) and physical inactivity (43.5% vs. 20.5%, respectively) compared to non-Hispanic Whites after adjusting for age and education (7).

In addition to the differences in T2D, obesity, and physical inactivity rates, Hispanics or Mexican Americans may be at a higher risk for T2D because of other lifestyle and SES characteristics. These characteristics will be further discussed in the sections 2.2.5 Acculturation, 2.2.6 Socioeconomic Status, and 2.2.7 Food Insecurity.

T2D is most commonly seen in older adults. In 2008, the prevalence of diagnosed diabetes was the highest among adults 60 and older (19.1%), and in 2005, approximately half of the new diabetes diagnoses belonged to those between the ages 40 and 59 years (1). Aging has been reported to be related to a higher risk of T2D independently of SES and ethnicity (7).

The prevalence of diabetes does not seem to considerably differ between men and women, but the impact of complications from diabetes may be greater for women than men (60, 96). This could be due to the gender differences in T2D risk factors: women have been reported to be more likely to have low SES, be more physically inactive when they age, and be exposed to gestational diabetes compared to men (60).

Therefore, it is necessary to take gender into account when examining the associations of T2D and its risk factors.

Among the other demographic factors, marital status may also be related to T2D prevalence indirectly through lifestyle factors. Data from the 1999-2002 National Health Interview Surveys (97) indicated that married adults were less likely to smoke and engage in heavy drinking, and they were more likely to be physically active and have better health status compared to divorced, widowed, or never married adults. It is not known whether marital status remains significantly related to T2D after controlling for such potential risk factors.

In summary, existing literature suggests that demographic factors, such as aging, and Hispanic or Mexican American ethnicity, are related to a higher risk of T2D. In addition to race/ethnicity, gender and marital status may influence the risk of T2D through other lifestyle behaviors.

2.2.5 Acculturation

Acculturation is “a process, in which individuals whose primary learning has been in one culture adopt attitudes, values, and behaviors from another culture” (40). Although more comprehensive measures of acculturation exist (98), single questions, such as the primary language spoken at home, generational (migration) status as determined by place of birth, and years of residence in the U.S., or small-scales involving various combinations of these questions are commonly used as proxy measures of acculturation (41, 44, 46, 52, 99-101).

Previously published studies have shown a link between acculturation status and diabetes, but the directions of associations have been contradictory. Sundquist, et al. (42) reported that Mexican-born adults included in the NHANES III had a lower risk of T2D than U.S.-born adults after controlling for age and education. On the other hand, Mainous, et al. (41) found that Hispanics, including Mexican Americans and others, with less (vs. higher) acculturation were at a greater risk for diabetes after controlling for race/ethnicity, age, sex, BMI, routine place of health care, health care coverage, and education.

The inconsistent results between these studies may be because of the methodological differences in the acculturation and diabetes status measures used for analyses. Acculturation measures included the country of birth and language use in one (42), and a five-item scale in the other study (41). Sundquist et al. (42) confirmed T2D status by a lab test and medical history, but Mainous et al. (41) used self-reported diabetes assessment, which did not differentiate type 2 from type 1 diabetes. Furthermore, the sample in the Mainous, et al.'s study was comprised of Hispanics from various origins, whereas Sundquist, et al.'s sample included only Mexican

Americans, who may not be similar to the other Hispanics because of cultural, health (102), or SES characteristics (12). More importantly, potential confounders, such as alcohol intake, cigarette smoking, physical activity, dietary intake, and family history of diabetes, were not taken into account in any of these reports. Further research is needed to clarify these associations.

The existing literature also points out the significant associations between acculturation and T2D risk factors (102). Published studies have indicated that acculturation was positively related to BMI (44) and obesity (30) among Puerto Rican women, and overweight or obese status among Hispanics (43, 45). Additionally, previous research has shown that cigarette smoking (30, 103) and alcohol intake (43) were positively associated with higher acculturation status, especially among Hispanic women. From these studies, higher acculturation appears to be related to conditions that would be likely to increase the risk for T2D. However, published reports also indicated a healthier lifestyle behavior – greater leisure-time (46) or non-occupational physical activities(47) – among highly acculturated Hispanics in comparison to their less acculturated counterparts. Hence, acculturation may also have protective influences against T2D.

Dietary intake patterns pertinent to increased risk for T2D have also been shown to be related to acculturation. Fiber intake has been reported to be greater among less (vs. more) acculturated Mexican Americans (49, 52), but previous studies showed inconsistent results in terms of fruit and vegetable intake. Less acculturated individuals were more likely to have higher intakes of fruits and vegetables among Mexican American (53) and Hispanic adults (54). However, other research among elderly Puerto Ricans and Dominicans (aged 60-92 yr) suggested a higher intake of fruits and vegetables among more (vs. less) acculturated individuals (104), probably because of ethnic subgroup, age, or lifestyle differences between the study samples.

The direction of the associations between dietary fat intake and acculturation has been inconsistent. While research among Mexican Americans (49) and Hispanic youths (31) indicated positive associations between acculturation and dietary fat intake, other research among Hispanic adults (55) suggested a negative association. Again, mixed results may be coming from the potential differences in samples' ethnicities and age, and acculturation measures used in these studies. Dixon, et al. (49) used country of birth and primary language spoken at home to evaluate acculturation, while Mazur, et al. (31) used primary language spoken by the parents, and Woodruff, et al. (55) used language preference and ethnicity of social contacts as their acculturation measures.

Published literature seems to be more in agreement regarding positive associations between acculturation and soft drink consumption among Puerto Ricans

(50, 51), and simple sugar intake among elderly Hispanics (48).

There also appears to be a significant association between acculturation and food insecurity. An analysis of Hispanic youths in NHANES III (31) indicated that acculturation was positively related to food insufficiency, which is a limited measure of food insecurity. Food insufficiency is defined as the condition of limited amount of foods within the household or insufficient food intake (105). Less acculturated Hispanics were less likely to cut adult meal sizes, although they were socioeconomically disadvantaged. According to Frisbie et al. (106), this may be because of a concept referred to as "culture-based protection" or "buffering," which provides explanations for the health-related advantages of immigrants. The authors suggested that immigrants are mostly comprised of healthier persons, and they tend to prohibit risky behaviors, such as smoking or drinking, and promote healthy behaviors via stronger familial and social support networks; but, the benefits of cultural buffering tend to diminish as acculturation increases.

Overall, acculturation seems to be related to T2D as well as several potential T2D risk factors such as obesity, physical inactivity, smoking, alcohol and certain dietary intake patterns, and food insecurity. However, it is not clear whether acculturation would be a significant factor influencing the associations of food insecurity and T2D after controlling for other likely T2D risk factors. Furthermore, it is not known whether these associations would differ between Mexican Americans and non-Hispanic Whites because published literature does not provide any studies with such a comparison.

2.2.6 Socioeconomic Status

Measures of SES often consist of income assessments, which mostly represent the economic component of SES, and education or occupation, which often reflect more of a social dimension of SES (27, 107). Another measure, poverty income ratio (PIR) is also commonly used in national surveys as an indicator of SES (7, 27). PIR is the ratio of income to the poverty threshold, which is determined every year based on the minimum level of income that is needed to fulfill a satisfactory standard of living depending on the family size and composition (108).

Previous research indicated that low SES, as measured by income (26), PIR (7, 27), education (7, 26, 27), and occupation (27), were associated with a greater risk of diabetes among mixed racial samples after controlling for age and a limited number of other likely confounders. However, it is not clear whether these associations differ between Mexican Americans and non-Hispanic Whites after adjusting for various SES indicators and other likely T2D risk factors.

Low SES can be linked to T2D through many T2D risk factors. For example, published reports indicated that Hispanics with low SES were: more likely to have dietary intakes high in calories and fat (31), more likely to be smokers (28, 29), and more likely to be obese (30).

The link between low SES and T2D may also be attributed to the access to and use of health-related information and services. Individuals with low SES may be living in low SES neighborhoods with limited social support or access to high quality health care facilities (109, 110); or, they may have limited health care coverage, which can adversely affect their health status (111). Low SES is also related to low health literacy and negative attitudes toward accepting and practicing healthy behaviors (112).

Although previous research examined the associations between SES indicators and T2D, it is not known whether various SES indicators (i.e., education, PIR, employment status, health care coverage) would still be significantly related to T2D after controlling for other likely T2D risk factors. The associations of SES and food insecurity will be further discussed in the following section.

2.2.7 Food Insecurity

Food insecurity is defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (34). The United States Department of Agriculture (USDA) Household Food Security Survey Module (113) is widely used to measure food security. Until 2006, this module included three main categories to define various levels of household food security: food security, food insecurity without hunger, and food insecurity with hunger. According to the 2006 revisions, food security has been further divided into high food security and marginal food security categories. Food insecurity without hunger has been replaced by the term low food security, and food insecurity with hunger has been replaced by the term very low food security. A comparison of old and new classifications and definitions are shown in Table 1.

Table 1. Definitions of food security categories according to the USDA Household Food Security Survey Module (113)

Prior to 2006	2006 Classification	
Food security	High food security	Households with no problems accessing adequate food
	Marginal food security	Households with problems, at times, of accessing adequate food, but no or little changes in quality, variety, or quantity of food intake
Food insecurity without hunger	Low food security	Households with reduced quality or variety of diets, but showing no or little changes in quantity of food intake. No substantial disruption in normal eating patterns
Food insecurity with hunger	Very low food security	Households with disrupted eating patterns and reduced food intake at times during the year

The prevalence of food insecurity in the U.S. has not changed considerably since 1998 (39). The 2007 estimates indicated that 11.1% of American households were food insecure some time during the year, and 4.1% of American households had very low food security. Food insecurity rates are even higher among certain minorities such as Hispanics in comparison to non-Hispanic Whites (36.1% vs. 30.0%, respectively) (39).

Food insecurity and T2D

Published literature about the associations of food insecurity and T2D is scarce. To date, only two studies reported (37, 38) that food insecurity was related to T2D prevalence after controlling for SES, as measured by income and education. However, these studies had certain limitations.

The report by Vozoris, et al. (38) came from the 1996/1997 National Population Health Survey among Canadians. They only reported food insufficiency, which is a limited measure of food insecurity referring to the condition of limited amount of foods within the household or insufficient food intake (105). Furthermore, they accounted for a limited number of potential confounders such as age, gender, education and income levels, and they did not discriminate between type 1 and type 2 diabetes.

The other report by Seligman, et al. (37) came from the nationally representative NHANES 1999-2002. They reported a positive association between T2D and very low food security after controlling for age, race/ethnicity, parity, income, education, obesity, physical activity, and family history of diabetes. However, their analyses also had several limitations. First, only households with incomes 300% below the federal poverty level were included in this study, which may have biased the study's outcome by excluding food secure individuals. Secondly, they did not adjust for various SES indicators, such as employment status or health care coverage, and T2D risk factors (e.g., cigarette smoking, alcohol intake, dietary intake), or comorbidities. Third, they failed to identify how Hispanics differed from non-Hispanic Whites in the associations between food insecurity and T2D prevalence. Further, their analyses were based on only NHANES 1999-2002 data that limited the sample size and necessitated merging of the marginal and low food security categories. Therefore, they were unable to observe whether marginal food security and low food security have different associations with T2D.

Although literature about the associations of T2D and food insecurity has been limited, such a linkage can be expected since other studies support the relationships between food insecurity and various health conditions. For example, negative associations between food insecurity and self-reported health status (36, 114, 115), and between food insufficiency and physical activity limitations (116), physical functioning, major depression, and chronic health conditions (e.g., heart disease) (38) have been reported.

Potential mechanisms of the link between food insecurity and T2D

The associations between food insecurity and T2D could be attributed to several factors, and dietary intake is one of these factors. As mentioned earlier, lower intakes of fruits and vegetables (22), or dietary intake patterns characterized by higher consumption of fat and refined carbohydrates and lower consumption of fruits, vegetables, whole grains, fish, and poultry, have been positively associated with the development of T2D (25) independently of obesity. Drewnowski and colleagues (117, 118) suggested that food insecure households may have a preference for buying low-cost foods such as refined grains, added sugars, or fats, which are low in nutritional value but high in calories. This intake pattern may result in reduced consumption of healthier but more expensive foods, such as lean meats, fish, fresh vegetables, and fruits.

The lower nutritional quality of diets among people with food insecurity is supported by the published literature. A study among Canadian women showed that very low food insecurity was related to lower intakes of vegetables, fruits, and meat (116). Another study by Lee, et al. (36) using the NHANES III and the Nutrition Survey of the Elderly in New York State also reported that food insecurity among elderly persons was related to lower nutrient intakes (e.g., energy, protein, carbohydrate, saturated fat, niacin, riboflavin, vitamins B6 and B12, magnesium, iron, and zinc). Additionally, this study indicated that food insecurity was related to a higher nutritional risk, which was measured by a nutritional risk scale that included questions such as the number of meals/day, fruit/vegetable/milk intakes, dietary change due to health problems, and eating alone.

Food insecurity also may lead to T2D indirectly through other T2D lifestyle factors, such as cigarette smoking, alcohol consumption, and physical activity. Using data from the Panel Study of Income Dynamics (PSID), Jones, et al. (119) reported that food insecure women were slightly more likely to smoke, less likely to consume alcohol, and less likely to engage in vigorous physical activities than food secure women.

The relationship between food insecurity and T2D can also be modified or mediated by weight status. One might expect less likelihood of obesity among food insecure individuals because of inadequate access to food and reduced food intake. However, several reports have shown a positive relationship between food insecurity and obesity. Two separate reports, based on the analyses of the NHANES 1999-2002 data, indicated that women with marginal food security were more likely to be overweight (5) or obese, and women with low food security were more likely to be obese when compared to highly food secure women (5, 120). It was also reported that self-reported weight gain over the past year was higher for women with marginal, low, and very low food security when compared to women with high food security (120).

These studies suggest that intermediate levels of household food security (e.g., marginal and low food security) may pose a greater risk of obesity when compared to high food security. One of the potential mechanisms behind this relationship can be the increased risk of obesity resulting from consuming cheaper energy-dense foods, as suggested by Drewnowski et al. (117, 118). Another mechanism of action can be the cyclic eating patterns (121) that are characterized by repetition of underconsumption when adequate amount of food is not available and overconsumption of calorie-dense foods when foods become available (122, 123). Individuals with intermediate levels of food security may gain weight as a result of these eating patterns. In contrast, individuals in the households with very low food security may experience a significant reduction in the amount of their food intake, as compared to the individuals in the households with marginal and low food security. If so, this could eventually lead to weight loss (5, 120).

Some reports suggest that the relationship between food insecurity and body weight may be gender-specific. Wilde, et al. (120) indicated in their NHANES 1999-2002 analyses that women with marginal and low food security (vs. high food security) were more likely to be obese. For men, this association was statistically significant only for marginally food secure men. In a different analysis of the

NHANES 1999-2002 data, Hanson, et al. (5) reported greater likelihood of overweight or obesity among marginally or low food secure women, but they did not detect these associations among men. They found that men with low (vs. high) food security were less likely to be overweight. This gender difference might be related to the use of different coping strategies between men and women. Unlike women, who are more engaged in social networks that might help in coping with stress and food insecurity, men more often isolate themselves from others, thus getting less support, which may lead to lower energy intake compared to women (5).

In addition to the lifestyle behaviors and obesity, SES can be another potential mechanism of action for the relationship between food insecurity and T2D because several studies support the associations between food insecurity and various measures of SES (31, 35-38). Studies showed that individuals in the households with food insecurity were more likely to be poor (31, 35-38), unemployed (35, 38), and less educated (31, 36, 37) than their food secure counterparts.

Some research also indicated that food insecure individuals were more likely to participate in food assistance programs such as the Supplemental Nutrition Assistance Program (SNAP) or formerly known as the Food Stamp Program (FSP) (31, 35, 36, 124). The reason underlying this association may be that those who experience greater economic hardship may be more likely to participate in these programs (125). However, other studies did not confirm a difference in food security levels based on FSP participation (126, 127); insufficiency of the program benefits could be the reason for lower food security levels (128). These associations may also have been biased because food secure households may have underreported or food secure households may have overreported their FSP participation (126).

Overweight and obesity patterns among FSP participants may also influence the associations between food insecurity, SES, and T2D. An analysis of longitudinal data from the Panel Study of Income Dynamics among U.S. households (129) showed that FSP participation was associated with positive weight change among persistently food-insecure women when compared to persistently food secure women. Townsend, et al. (124) also reported, using cross-sectional data from the Continuing Survey of Food Intakes by Individuals (CSFII), that participation in the FSP was associated with a high risk of overweight among women, but not among men. Another longitudinal study among the elderly by Kim, et al.(130), however, reported that elders with food insecurity who participated in food assistance programs, such as FSP or Home-delivered Meals, were less likely to be overweight than food insecure participants who did not participate in those programs. The contradictory result found by Kim, et al. (130) could be partly due to the fact that their sample was older than the samples in other studies, and that self-reported weight and height among elderly may be less accurate than in younger adults.

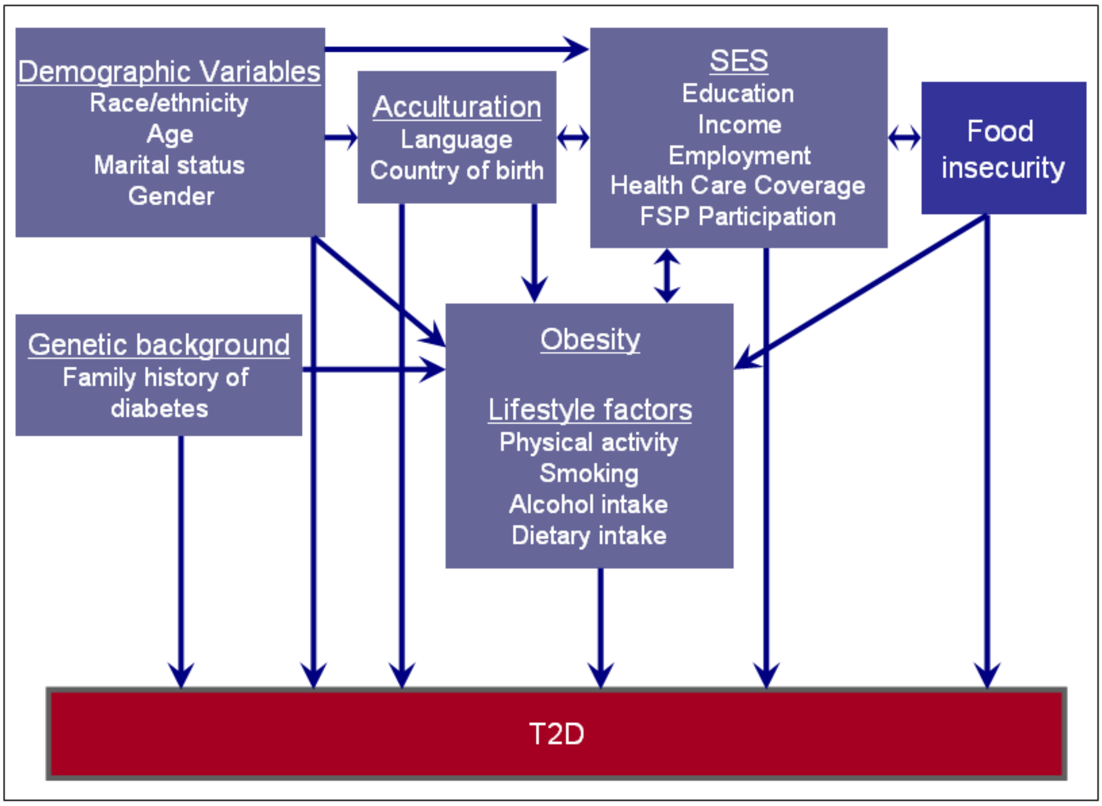
Another potential mechanism of action for the link between food insecurity, SES, and T2D could be through cyclic eating patterns and obesity as a result of monthly distribution of benefits by food assistance programs (121, 131). This pattern involves undereating followed by overeating in order to compensate when adequate amount of food is available (122, 123), and it is associated with an increase in body fat and a faster weight gain upon refeeding (132). Duska, et al. (133) reported that acute starvation for 60 hours decreased insulin sensitivity among obese subjects, with and without T2D. During starvation or fasting, plasma FFA concentration rises because of the increased ketone body utilization to conserve glucose in order to provide enough energy to the central nervous system (134, 135). Elevated levels of FFAs as a result of fasting can cause insulin resistance in skeletal muscle and liver (64, 65), and eventually lead to T2D, as explained in the previous sections.

2.3 Summary of the Literature Review

In summary, T2D is a major chronic disease currently affecting approximately 24 million Americans, thus significantly increasing the national economic burden of treating people with T2D. Although T2D has a genetic component (4-6), many other factors such as obesity (13) and lifestyle characteristics (physical inactivity (14-17), certain dietary (22-25) and alcohol (20, 21) intake patterns, and cigarette smoking (18, 19)) have been reported to influence T2D etiology. Additionally, studies point out the existence of associations between demographic factors (e.g., aging, various minority race/ethnicities) (7-9), acculturation, and T2D (41, 42). Furthermore, food insecurity (37, 38) and SES indicators such as lower levels of income and education (7, 26) have also been associated with a greater prevalence of T2D.

Food insecurity has been reported to be linked to T2D (37, 38) as well as T2D risk factors such as obesity (131), poor dietary intakes (36, 116), low SES (31, 35-38, 124), and acculturation (31, 35). Figure 1 summarizes a framework of complex associations between various factors in relationship to T2D risk. These complex associations are not well studied to understand whether food insecurity is related to T2D independently of SES and other likely T2D risk factors.

Figure 1. A framework of factors in relationship to type 2 diabetes risk



FSP: Food Stamp Program, SES: Socioeconomic status.

There are several gaps in the existing literature regarding the associations between food insecurity and T2D prevalence. First, the current literature does not reveal whether all levels of food insecurity are related to T2D because previous analyses have been conducted in smaller samples, which did not allow all 4 levels of food security (high, marginal, low, and very low) to be examined. Secondly, it is not known whether food insecurity would be associated with T2D after controlling for a greater number of SES indicators (e.g., employment, health care coverage), in addition to the indicators that are commonly used in the previous literature (e.g., education, income). Furthermore, it is not known whether these associations would still be significant after accounting for obesity, lifestyle factors, acculturation, and other likely diabetes risk factors.

The aforementioned associations need to be specifically examined among Mexican Americans because they represent the largest segment among Hispanics in the U.S. (65.5%) (12), and they also have substantially higher age-adjusted rates of diagnosed diabetes compared to non-Hispanics whites (11.9% vs. 6.6% in 2004-2006, respectively) (11). Additionally, Mexican Americans have greater prevalence of obesity and physical inactivity than non-Hispanic Whites (7), and their food intake behaviors have been reported to change as they become more acculturated (49, 52, 53). Furthermore, they have lower levels of income and education (7, 43), and higher rates of poverty (136) and food insecurity (39) compared to non-Hispanic Whites. Therefore, understanding these complex associations among Mexican Americans is an important nutrition and health issue. Moreover, determining the potential racial/ethnic differences in these associations between Mexican Americans and non-Hispanic Whites has the potential to contribute to the development of more effective interventions, health care programs, and policies to prevent T2D in these populations.

This study focused only on Mexican Americans instead of other Hispanic subgroups or all Hispanics combined because cultural and socioeconomic characteristics or health outcomes of each Hispanic subgroup may vary (12, 102).

Hence, assuming that Hispanics are one homogenous ethnic group could produce erroneous results. Additionally, the NHANES 1999-2004 was used to conduct this study, and this data set does not provide adequate sample sizes for the other Hispanic subgroups to generate reliable estimates.

Using the NHANES 1999-2004 data set to perform these analyses provides an opportunity to examine these associations both for Mexican Americans and non-Hispanic whites in a nationally representative sample. Because relevant research in this field is limited in terms of the sample size and external validity, conducting this study using the NHANES 1999-2004 with adequate sample size for Mexican Americans and non-Hispanic Whites will provide the results that can be generalized with a high confidence level.

CHAPTER III. METHODS

The literature review that was summarized in Chapter II pointed out that there were gaps in clarifying the associations between food insecurity, various SES indicators, T2D risk factors, and T2D. It also pointed toward the need for research to determine whether these associations differed between Mexican Americans and non-Hispanic Whites. Therefore, this study was conducted, as a secondary data analysis, to examine these associations among Mexican American and non-Hispanic White adults in a nationally representative sample form the NHANES 1999-2004. The use of this data set allows for the generalization of the study findings at the national level.

3.1 Aims, Objectives, and Hypotheses

This study aimed to examine the associations of food insecurity, SES indicators, and T2D prevalence among Mexican Americans and non-Hispanic Whites in a nationally representative sample of adults from the NHANES 1999-2004.

This study's objectives were:

1) To identify whether food insecurity is related to T2D independently of SES indicators after adjusting for obesity, lifestyle, demographic characteristics, acculturation, and other likely confounders (e.g., family

history of diabetes and comorbidities) in a nationally representative sample of Mexican American and non-Hispanics White adults.

The intent of this study was to examine a wide range of SES indicators (i.e., education, PIR, employment, health care coverage, and FSP participation), lifestyle factors (i.e., physical activity, cigarette smoking, alcohol and dietary intakes), and demographic characteristics (i.e., race/ethnicity, age, gender, marital status).

Given the previous research (37, 38) suggesting a significant relationship between a limited measure of food insecurity and T2D after adjusting for education and income, it was hypothesized that food insecurity would be positively associated with T2D prevalence independently of SES indicators and other potential T2D risk factors.

2) To examine the racial/ethnic differences in these associations between Mexican American and non-Hispanic White adults.

Given the existence of socioeconomic disparities between Mexican Americans and non-Hispanic Whites, it was hypothesized that food insecurity and SES indicators would be stronger determinants of T2D among Mexican Americans.

3.2 Data Source and Survey Design

The data from the NHANES 1999-2004 were used for this study. The

NHANES is a series of cross-sectional surveys, conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). The surveys are designed to assess the health and nutritional status of the non-institutionalized U.S. population. Every year, the survey examines about 5,000 individuals from counties located across the country. Since 1999, data have been collected continuously every year and released in 2-year data segments.

The NHANES has a complex, multistage, probability sampling design that consists of four stages. In stage one, single or groups of counties, called primary sampling units (PSUs), are randomly selected. In stage two, the PSUs are divided into segments (e.g. city blocks). In stage three, a sample is randomly drawn from households within each segment. Finally in stage four, individuals are randomly selected within the households. Non-Hispanic blacks, Mexican Americans, low income White Americans (beginning in 2000), adolescents, and persons who are 60 years or older are oversampled in order to obtain more valid estimates among these subgroups because they are thought to be at particular health and nutritional risk.

The NHANES data are collected through two primary components: face-to-face home interviews and health examinations at a mobile exam center (MEC). MECs consist of travel trailers with necessary equipment for health examinations, and they are staffed by trained medical personnel including physicians, medical/health technicians, and dietary/health interviewers. Many of the medical personnel speak both English and Spanish. In-home interview results include data about demographic, socioeconomic, dietary, and health-related information. Health examinations at the MEC include information collected by performing medical and dental exams, physiological and anthropometric measurements, laboratory tests, and 24-hour dietary recall interviews. Medical reports and compensation are provided to the participants.

3.3 Analytical Sample

Data used for this study were obtained from the publicly available NHANES files (available at: http://www.cdc.gov/nchs/nhanes.htm) for the survey periods of 1999-2000 (n=9,965), 2001-2002 (n=11,039), and 2003-2004 (n=10,122). The response rates for the household interview and health examination, respectively, were 82% and 76% for 1999-2000, 84% and 80% for 2001-2002, and 79% and 76% for 2003-2004. After combining these three segments, data from 14,700 adults aged 20 to 84 years were available for the analyses. Because age was top-coded by the NCHS at 85 years, the higher age limit was set to 84 years. Participants who did not have both the home interview and MEC examination data available (n=955) and those with unknown diabetes cases (n=10) were excluded from the sample. Other exclusion criteria included being pregnant (n=772) or having type 1 diabetes (n=27), defined as being diagnosed with diabetes before the age of 30 and having started insulin treatment within 1 year from the time of the diagnosis. The final analytical sample included 12,944 participants.

3.4 Measures and Variables Used

The NHANES variables used for the analyses are shown in Appendix A.

Type 2 diabetes

Since self-report of diabetes is a valid measure of diabetes status, as indicated by 97.2% of total agreement between self-reported diagnosis and medical records (137), self-reported diabetes was used in this analysis. Thus, T2D was determined if the participants responded, “yes” to the question “Other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?” However, since approximately one-third (30.1%) of diabetes cases among adults in the U.S. is undiagnosed (138), fasting plasma glucose levels of ≥126mg/dL (139) after a fasting period of 8 to 24 hours were also used to determine T2D status.

Food insecurity

Household food security status was measured by data collected via the 18-item U.S. Household Food Security Survey Module (FSSM) developed by the USDA (34). The FSSM was answered by one adult respondent for the household. The survey asks about household circumstances over the past 12 months (See Appendix B). The NCHS released the FSSM data after scoring and classifying it into four categories according to the number of affirmative responses: high food security (0 affirmative response), marginal food security (1-2 affirmative responses), low food security (3-7 affirmative responses), and very low security (8-18 affirmative responses) (34). Higher income households (≥400% federal poverty line) were automatically classified by the NCHS as highly food secure. For the current analyses, food security categories were combined into three categories (high food security, marginal/low food security, and very low food security) to overcome small sample sizes in some of the models.

Socioeconomic status

The main SES indicators included in this investigation were: education, poverty-income ratio (PIR), and employment status, as these are commonly used to indicate a person's SES (27, 140). Education, as ascertained by asking what was the highest grade or level of school the respondents completed or the highest degree they received, was classified by the NCHS as less than high school, high school diploma including GED, and more than high school. Education was further categorized into low (less than high school) and high (high school diploma including GED/more than high school) education groups for the current analyses. The PIR is the ratio of income to the poverty threshold, which is determined every year to establish a minimum level of income that is needed to fulfill a satisfactory standard of living depending on the family size and composition (108). PIR values below one indicate incomes less than poverty threshold while PIR values of one or greater indicate incomes above the poverty level. Employment status was determined based on a question regarding if the person surveyed had worked during the week prior to the interview. The original four employment categories established in the NHANES data set were dichotomized for the analyses into employed (working at a job or business/ with a job or business but not at work) and unemployed (looking for work/ not working at a job or business) for the analyses.

Additional SES indicators included household participation in the FSP (currently known as SNAP) and health care coverage. FSP participation was determined if the participants answered "yes" to the question asking if the respondent was authorized to receive Food Stamps for the last 12 months prior to the interview. Having health care coverage was determined if the participants responded "yes" to the question, "Are you covered by health insurance or some other kind of health care plan?"

Obesity

BMI as a measure of overall weight status was calculated as weight in kilograms divided by height in meters squared. Weight was measured on an electronic digital scale, and participants wore only underwear, disposable paper gowns, and foam slippers when measured. Height was measured using a stadiometer. BMI was classified as obese (≥30.0), overweight (25.0 to 29.9), normal (18.5 to 24.9), and underweight (<18.5), as defined by the standards of the Centers for Disease Control and Prevention (141). WC was used as a measure of visceral (central) adiposity. Participants with WC of greater than 102cm for men and 88cm for women were classified as having a high WC, based on the clinical guidelines of the National Heart, Lung, and Blood Institute (142).

<u>Lifestyle factors</u>

Physical activity: Leisure-time physical activity (LTPA) level included moderate or vigorous activities done by the participants during the 30 days prior to the interview. Assessed LTPAs included walking, jogging, dancing, fishing, baseball, tennis, skating, surfing, and various other leisure time moderate or vigorous intensity activities. Moderate intensity was defined as activities that caused light sweating or a slight to moderate increases in breathing or heart rate. Vigorous intensity was defined as activities that caused heavy sweating or large increases in breathing or heart rate. The metabolic equivalency (MET) scores for each LTPA were determined by the NCHS based on previous research (143). One MET is equivalent to the energy expended in a resting state of an individual, which is about 3.5 ml of oxygen per kilogram of body weight per minute (144). Total LTPA in MET minutes (MET-min) per 30 days was calculated by multiplying the frequency of the moderate and vigorous LTPAs in the past 30 days, the duration of LTPA each time, and the assigned MET scores. These totals were then summed to calculate each individual's activity MET-min per 30 days. Daily total LTPA MET-minutes (MET-min/d) were calculated by dividing total LTPA MET-min by 30. If participants had responded, "no" or "unable to do activity" to the question asking if they did any moderate or vigorous activities for at least 10 minutes over the past 30 days, the LTPA was recorded as zero. Daily total LTPA was dichotomized into sedentary (MET-min/d=0) and active (MET-min/d >0) based on the data distribution patterns.

Cigarette smoking: Smoking status was determined from two questions: "Have you smoked at least 100 cigarettes in your entire life" and "Do you now smoke cigarettes?" Participants were considered to be smokers if they responded "yes" to both questions. The smoking status was confirmed by having serum cotinine levels of >85nmol/L (15ng/mL) (145). Among the participants classified as smokers, whose cotinine level data were available, 92.0% of those were confirmed as smokers.

Alcohol intake: Alcohol intake status was based on a question that asked participants if they consumed at least 12 drinks (liquor, beer, wine, wine cooler, and other types of alcoholic beverages) in any one year. Participants were classified as drinkers if they said, “yes” and as nondrinkers if they responded, “no” One drink referred to a 12 oz. beer, a 4 oz. glass of wine, or an ounce of liquor. Although the average number of alcoholic beverages consumed per day was also calculated, it was not used because of the large proportion of missing data (18.1%).

Dietary intake: Dietary intake was assessed through a 24-hour dietary recall. The dietary recall interview had been conducted in the MECs to obtain the types and amounts of foods and beverages consumed from midnight to midnight the day before the interview. NHANES 1999-2002 included one day of dietary intake data, whereas NHANES 2003-2004 included two days of intake data. The first day’s data were collected at the MEC interview, and the second day’s data were collected by a telephone follow-up. Only the first day’s data of NHANES 2003-2004 were included in the current analyses. Total daily intake levels of energy (kcal/day), protein (g/day), carbohydrate (g/day), total fat (g/day), saturated fatty acids (SFA) (g/day), monounsaturated fatty acids (MUFA) (g/day), and polyunsaturated fatty acids (PUFA) (g/day) were available in the NHANES database. Based on these total absolute consumption levels, macronutrient intakes, as percentages of calories, were calculated for the current analyses. Based on the recommended dietary fiber intake of 14g/1000kcal (146), fiber intake was dichotomized into two groups: adequate fiber intake ($\geq$ 14g/1000kcal), and low fiber intake (<14g/1000kcal). Cholesterol intake was dichotomized into high (≥300mg) and low cholesterol intake (<300mg), because less than 300mg/day of dietary cholesterol intake is recommended for cardiovascular health (146, 147).

Demographic characteristics

Race/ethnicity, age, gender, and marital status were the demographic characteristics examined in the analyses. Race/ethnicity options in the NHANES database included Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, and other race including multi-racial individuals. Among Hispanics, only Mexican Americans were used for the analyses. Other Hispanics and other racial/ethnic groups were included in the analytical sample, but their results were not interpreted.

Age was mostly used as a continuous variable, but a categorical age variable was also constructed to improve the model fit in some of the models. The categorical age variable was classified into 20-39, 40-59, and 60-84 years of age. The 20-year increments for age variable were determined by the distribution of T2D among these age groups (20-39yr: 1.8%, 40-59: 8.6%, 60yr and older: 18.9%; adjusted for study design). Further dividing these age groups would result in some age categories with too few people with T2D. Thus, 20-year increments were more appropriate for the analyses.

Gender was coded as a dichotomous variable (male and female). Marital status was classified into having a partner (married or living with a partner) and having no partner (widowed, divorced, separated, or never married).

Acculturation

Language use at home and country of birth were used as proxy measures of acculturation, which is a common practice in the relevant literature (41, 44, 46, 52).

The answer options for the language use at home were different for Hispanics and non-Hispanics in the database. Hispanics had the option to select one of five answer options (only Spanish, more Spanish than English, both equally, more English than Spanish, only English). Non-Hispanics' answers included only three options (English, Spanish, other language). For the current analyses, these options were combined into three categories: 1) English or more English than Spanish; 2) Both equally; and, 3) Spanish or more Spanish than English / other.

Because of the difference in the answer options between the two racial/ethnic groups for the language variable, country of birth was also used as a proxy measure for acculturation. Being born outside of the U.S has been shown to be related to the measures that are relevant to this study such as physical inactivity (46), and dietary intake (52). Further, country of birth has been reported to be a stronger predictor of dietary intake changes than language among Mexican American women (52).

Previously published reports has also indicated that place (country) of birth or generational status (first vs. second generation) has been highly correlated with more comprehensive language-based acculturation measures (r=0.69) (99, 100).

Country of birth was classified into two categories: US-born (born in 50 US States or Washington, DC) and foreign-born (born in Mexico or elsewhere).

Other Covariates

To prevent potential confounding by other health conditions that may affect participants' lifestyle behaviors, comorbidity status was included as a covariate. Participants were classified as having comorbidities if they answered, "Yes" to the questions asking if they had ever been told by a doctor or other health professional that they had congestive heart failure, angina/angina pectoris, heart attack, or stroke. Family history of diabetes was also included as a covariate. Subjects were defined as having a family history of diabetes if they responded, "Yes" to the question, "Including living and deceased, were any of your biological, that is, blood relatives including grandparents, parents, brothers, or sisters, ever told by a health professional that they had diabetes?"

The proportion of missing data were 4.1% for household food security, 0.2% for education, 8.9% for PIR, 0.04% for employment, 1.3% for health care coverage, 61.0% for FSP participation, 3.1% for BMI, 4.7% for WC, 0.04% for physical activity, 0.2% for cigarette smoking, 7.8% for alcohol intake, 5.3% for energy, macronutrients, fiber, and cholesterol intakes, 3.3% for marital status, 0.3% for country of birth, 0.1% for language use at home, 0.5% for comorbidities, and 2.2% for family history of diabetes. T2D, race/ethnicity, age, and gender did not have any missing data.

3.5 Statistical Analyses

Data analyses were conducted using SPSS 16.0 for Windows (SPSS Inc., Chicago IL, 2007). SPSS Complex Samples module was used to adjust for the unequal sample selection probabilities, nonresponse, stratification, and clustering aspects of the NHANES. As recommended by the NCHS, 6-year sample weights for these analyses were calculated based on the 4-year MEC weights for NHANES 1999-2002 and 2-year MEC weights for NHANES 2003-2004:

6-year sample weight for 1999-2002 = 2/3 of 4-year sample weight

6-year sample weight for 2003-2004 = 1/3 of 2-year sample weight

Statistical analyses were conducted in several steps. First, the frequencies and variable distributions were examined. Second, independent sample t-tests, Chi-square tests of independence, and General Linear Modeling were used to evaluate the bivariate associations by T2D, food security, race/ethnicity, and acculturation status.

Correlations were analyzed via Spearman Rho calculations.

Multivariate analyses were performed by using logistic regression. First, associations of food insecurity and SES indicators (PIR, education, employment, health care coverage, FSP participation) with T2D as the dependent variable were examined after adjusting for demographic factors (race/ethnicity, age, gender, marital status) and acculturation. Next, associations of food insecurity and SES indicators with T2D were examined in the final model after further adjusting for obesity, lifestyle factors (BMI/WC, physical activity, cigarette smoking, alcohol intake, dietary intake), demographic factors, acculturation, and other covariates (family history of diabetes, comorbidities). First-order interactions with the independent variables were examined and included in the models if they were found to be statistically significant ($p<0.05$). Finally, Mexican Americans and non-Hispanic Whites were examined separately using the final multivariate model to see the racial/ethnic differences between the two groups.

Bonferroni adjustments were performed for the variables that exhibited more than one degree of freedom. Variables that exhibited a two-tailed p value of less than 0.05 or a 95% confidence interval of the odds ratio that did not include the value of one were considered to be statistically significant. Multicollinearity was determined by the tolerance level (excluded if <0.25) and VIF (excluded if >4). Multicollinearity was examined between total fat and different fat types including SFA, MUFA, PUFA, and between BMI and WC.

CHAPTER IV. RESULTS

This chapter presents first, the results from bivariate analyses including participant characteristics by diabetes, food security, race/ethnicity, and acculturation status. Next, the results from multivariate analyses including the models examining the associations between food insecurity, SES indicators, and T2D are provided.

4.1 Bivariate Analyses

Bivariate test results, obtained through Chi square (χ^2) test, independent samples t-test, and general linear modeling, are shown in the Tables 2 through 7.

4.1.1 Analytical Sample Characteristics

The characteristics of the analytical sample (n=12,944) and excluded participants (n=1,756) were examined to detect any major differences in SES and demographic characteristics. Participants in the analytical sample were more likely to be male (48.9% vs 5.7%, p=0.000), older (mean age 45.9 vs 30.1 years, p=0.000), US-born (84.8% vs 79.0%, p=0.015), and above poverty threshold (86.3% vs 77.7% with PIR>1, p=0.000) than those who were excluded. These differences might be partially due to the fact that pregnant women were excluded from the sample. No significant differences were detected between the two groups regarding food security, education level, employment, health care coverage, and marital status characteristics (Data not shown).

4.1.2 Participant Characteristics by Type 2 Diabetes Status

About 11.8% of the analytical sample was determined to have T2D. Tables 2 and 3 illustrate the participant characteristics by diabetes status.

Food security, SES, acculturation, and demographic characteristics by T2D status

On average, participants with T2D (vs. those without diabetes) were older ($p=0.000$) (Table 2). Food insecurity, and low SES, as indicated by FSP participation, PIR, employment, and education levels were more common among individuals with T2D ($p<0.05$). Greater percentages of participants with T2D had health care coverage compared to individuals without diabetes ($p=0.000$). A gender by PIR status interaction indicated that participants with T2D were less likely to have a high PIR (>1) among women, but not among men ($p=0.005$). Country of birth and language use at home were not statistically different between participants with and without T2D.

Racial/ethnic differences are discussed in section 4.1.4.

Table 2. Food security, socioeconomic status, acculturation, and demographic characteristics by type 2 diabetes status among adults, 20-84 years, in the NHANES 1999-2004

	All (n=12,944)		No diabetes (n=11,413)		T2D (n=1,531)		P value
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
Estimated US population, in millions	193.2	-	177.4	91.8 (0.3)	15.8	8.2 (0.3)	-
Mexican American	2,955	7.3 (0.9)	2,522	7.3 (0.8)	433	6.9 (1.2)	0.000 [c]
Non-Hispanic White	6,363	71.4 (1.7)	5,766	72.1 (1.6)	597	64.2 (2.7)	
Other race/ethnicity	3,626	21.3 (1.4)	3,125	20.6 (1.4)	501	28.9 (2.3)	
Age, mean	12,944	45.9 (0.3)	11,413	44.7 (0.3)	1,531	59.0 (0.6)	0.000[d]
Age, %: 20-39yr	4,295	39.1 (0.8)	4,214	41.8 (0.8)	81	8.1 (1.1)	0.000 [c]
40-59yr	4,139	39.2 (0.6)	3,699	39.0 (0.7)	440	41.3 (1.5)	
60-84yr	4,510	21.7 (0.6)	3,500	19.2 (0.5)	1,010	50.2 (1.9)	
Male	6,512	48.4 (0.4)	5,732	48.4 (0.4)	780	51.0 (1.3)	0.112 [c]
Female	6,432	51.1 (0.4)	5,681	51.2 (0.4)	751	49.0 (1.3)	
Marital status:							0.423 [c]
Have partner	7,706	64.1 (0.8)	6,803	64.3 (0.9)	903	62.5 (2.1)	
No partner	4,808	35.9 (0.8)	4,231	35.7 (0.9)	577	37.5 (2.1)	
US-born	9,983	84.8 (1.3)	8,820	84.8 (1.2)	1,163	84.7 (2.2)	0.945 [c]
Foreign-born	2,924	15.2 (1.3)	2,564	15.2 (1.2)	360	15.3 (2.2)	
Language use at home:							0.489 [c]
English	9879	86.3 (1.4)	8783	86.4 (1.3)	1096	85.1 (2.3)	
English/Spanish equally	512	2.1 (0.5)	443	2.1 (0.5)	69	2.5 (0.7)	
Spanish or other	2546	11.6 (1.1)	2180	11.5 (1.0)	366	12.4 (1.9)	
High FS	9,818	84.2 (0.6)	8,687	84.6 (0.7)	1,131	80.3 (1.4)	0.001 [c]
Marginal FS	878	5.4 (0.4)	755	5.3 (0.4)	123	6.9 (1.0)	
Low FS	1,126	6.5 (0.4)	993	6.5 (0.4)	133	6.2 (0.9)	
Very low FS	585	3.9 (0.3)	495	3.6 (0.3)	90	6.6 (1.1)	
High PIR (≥1)	9,621	86.3 (0.7)	8,563	86.6 (0.7)	1,058	83.1 (1.3)	0.016 [c]
Low PIR (<1)	2,176	13.7 (0.7)	1,858	13.4 (0.7)	318	16.9 (1.3)	
Education:							0.000 [c]
High school or more	8,693	79.6 (0.7)	7,897	80.7 (0.7)	796	66.9 (1.6)	
Less than high school	4,224	20.4 (0.7)	3,493	19.3 (0.7)	731	33.1 (1.6)	
Employed	7,243	65.5 (0.7)	6,766	67.6 (0.7)	477	40.9 (2.0)	0.000 [c]
Unemployed	5,696	34.5 (0.7)	4,643	32.4 (0.7)	1,053	59.1 (2.0)	
Have health care coverage	10,162	82.0 (0.7)	8,845	81.4 (0.7)	1,317	88.9 (1.0)	0.000 [c]
No health care coverage	2,609	18.0 (0.7)	2,416	18.6 (0.7)	193	11.1 (1.0)	
Participate in FSP	815	13.2 (1.0)	680	12.9 (1.0)	135	16.9 (1.9)	0.015 [c]
No participation in FSP	4,263	86.8 (1.0)	3,739	87.1 (1.0)	497	83.1 (1.9)	
Women, high PIR	4,644	42.8 (0.5)	4,165	43.2 (0.6)	479	37.8 (1.5)	0.005[c]
Women, low PIR	1,173	8.0 (0.4)	985	7.8 (0.5)	188	10.2 (1.0)	
Men, high PIR	4,977	43.5 (0.5)	4,398	43.4 (0.5)	579	45.3 (1.4)	
Men, low PIR	1,003	5.7 (0.3)	873	5.6 (0.3)	130	6.6 (0.8)	

[a] Analytical sample size (n=12,944) is unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each diabetes category.

[c] Refers to χ^2 test.

[d] Refers to independent samples t-test.

FS: Food security; FSP: Food Stamp Program; PIR: poverty income ratio; SE: standard error; US: United States.

Obesity, lifestyle, and other T2D risk factor characteristics by T2D status (Table 3)

Individuals with T2D had higher BMI and WC, and they were more likely to be obese, sedentary, nonsmokers, and nondrinkers in comparison to participants without diabetes ($p<0.001$) (Table 3). Their total energy and fiber intakes, and percentage of calories from carbohydrate were lower, whereas their percentages of calories from protein and total fat intake were higher ($p<0.05$). Greater proportions of people with T2D had comorbidities and family histories of diabetes when compared to those without diabetes ($p<0.001$).

4.1.3 Participant Characteristics by Food Security Status

SES, acculturation, and demographic characteristics by food security status

Population estimates of household food security prevalence were 84.2% (156.1 million) for high food security, 5.4% (10.0 million) for marginal food security, 6.5% (12.0 million) for low food security, and 3.9% (7.2 million) for very low food security.

Individuals with household food insecurity were more likely to be younger, less acculturated, and have no partner ($p<0.000$) compared to those with high food security (Table 4). They also seemed to have a low SES as indicated by lower levels of PIR, education, employment, and health care coverage, and higher FSP participation ($p<0.000$).

Table 3. Obesity, lifestyle, and other type 2 diabetes risk factor characteristics by diabetes status among adults, 20-84 years, in the NHANES 1999-2004

	All		No diabetes		T2D		P value
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
BMI, mean	12,546	28.1 (0.1)	11096	27.8 (0.1)	1450	32.3 (0.3)	0.000[c]
BMI, %:							0.000[d]
Underweight	201	1.9 (0.1)	197	2.0 (0.1)	4	0.2 (0.1)	
Normal	3,785	32.6 (0.6)	3,559	34.2 (0.7)	226	14.5 (1.4)	
Overweight	4,504	34.5 (0.7)	4,008	34.9 (0.7)	496	30.0 (1.6)	
Obese	4,056	31.0 (0.7)	3,332	28.9 (0.7)	724	55.2 (2.0)	
WC (cm), mean	12,340	96.3 (0.3)	10,917	95.2 (0.2)	1423	109.1 (0.7)	0.000[c]
WC, %: Normal	5,967	50.9 (0.9)	5,608	53.4 (0.9)	359	22.1 (1.5)	0.000[d]
High	6,373	49.1 (0.9)	5,309	46.6 (0.9)	1,064	77.9 (1.5)	
LTPA (MET-min/d)	12,939	148.9 (5.3)	11,408	151.9 (5.4)	1,531	115.4 (15.7)	0.025[c]
LTPA, %:							0.000[d]
Active	7,130	63.0 (0.9)	6,500	64.3 (0.8)	630	48.1 (1.8)	
Sedentary	5,809	37.0 (0.9)	4,908	35.7 (0.8)	901	51.9 (1.8)	
Nonsmoker	9,910	74.6 (0.7)	8,647	74.2 (0.7)	1,263	80.0 (1.3)	0.000[d]
Smoker	3,014	25.4 (0.7)	2,748	25.8 (0.7)	266	20.0 (1.3)	
Nondrinker	3,714	27.8 (1.3)	3,112	26.7 (1.4)	602	40.6 (1.7)	0.000[d]
Drinker	8,222	72.2 (1.3)	7,388	73.3 (1.4)	834	59.4 (1.7)	
Energy intake (kcal/d)	12,263	2,221.8 (12.3)	10,798	2,249.4 (12.0)	1,465	1,915.4 (34.8)	0.000[c]
Energy intake (kcal/d)							0.000[d]
1st quartile	3,062	1,060.8 (7.7)	2,512	1,061.7 (8.5)	550	1,054.4 (14.6)	
2nd quartile	3,068	1,663.0 (3.4)	2,678	1,664.8 (3.5)	390	1,645.3 (10.1)	
3rd quartile	3,067	2,240.6 (3.8)	2,735	2,242.2 (4.0)	332	2,221.7 (11.9)	
4th quartile	3,066	3,493.2 (19.4)	2,873	3,496.2 (20.4)	193	3,439.8 (69.0)	
Protein intake (% kcal/d)	12,261	15.3 (0.1)	10,798	15.1 (0.1)	1,463	16.7 (0.2)	0.000[c]
Carbohydrate intake (% kcal/d)	12,261	49.8 (0.2)	10,798	49.9 (0.2)	1,463	48.4 (0.5)	0.002[c]
Total fat intake (% kcal/d)	12,261	33.3 (0.2)	10,798	33.2 (0.2)	1,463	34.8 (0.4)	0.000[c]
Fiber, %:							0.000[d]
≥14g/1000kcal/d	1,126	7.2 (0.3)	883	6.7 (0.3)	243	13.1 (1.0)	
<14g/1000kcal/d	11,135	92.8 (0.3)	9,915	93.3 (0.3)	1,220	86.9 (1.0)	
Cholesterol, %:							0.715[d]
<300mg/d	7,956	64.9 (0.6)	7,015	64.9 (0.6)	941	64.3 (1.7)	
≥300mg/d	4,307	35.1 (0.6)	3,783	35.1 (0.6)	524	35.7 (1.7)	
No comorbidities	11,555	92.4 (0.4)	10,439	93.9 (0.3)	1,116	75.8 (1.7)	0.000[d]
Have comorbidities	1,323	7.6 (0.4)	927	6.1 (0.3)	396	24.2 (1.7)	
Family history DM:							0.000[d]
No	6,347	50.1 (0.8)	5,960	52.4 (0.8)	387	24.0 (1.6)	
Yes	6,318	49.9 (0.8)	5,216	47.6 (0.8)	1,102	76.0 (1.6)	

[a] Analytical sample size was unweighted; sample size totals for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each diabetes category.

[c] Refers to independent samples t-test. [d] Refers to χ^2 test.

BMI: Body mass index; DM: diabetes mellitus; LTPA: leisure time physical activity; SE: standard error; WC: waist circumference.

BMI: Underweight (<18.5), normal (18.5 to 24.9), overweight (25.0 to 29.9), obese (≥30.0); WC: high (>88cm in women, >102cm in men); LTPA: Active: MET-min/d>0., sedentary: MET-min/d≤0

Table 4. Socioeconomic status, acculturation, and demographic characteristics by household food security status among adults, 20-84 years, in the NHANES 1999-2004

	High FS	Marginal FS	Low FS	Very low FS	P value
	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	
Age, mean	9,818 / 46.9 (0.3)	878 / 41.4 (0.7)	1,126 / 39.9 (0.6)	585 / 41.9 (0.9)	0.000[c]
Age, %: 20-39yr	3,001 / 36.5 (1.0)	370 / 52.8 (2.4)	494 / 54.6 (2.1)	234 / 47.0 (3.0)	0.000[d]
40-59yr	3,104 / 39.9 (0.8)	263 / 32.5 (2.3)	360 / 34.3 (1.8)	230 / 42.5 (2.5)	
60-84yr	3,713 / 23.7 (0.6)	245 / 14.7 (1.4)	272 / 11.1 (1.0)	121 / 10.5 (1.8)	
Male	5,005 / 49.4 (0.4)	407 / 44.2(1.4)	565 / 48.5 (1.7)	276 / 46.1 (2.1)	0.012[d]
Female	4,813 / 50.6 (0.4)	471 / 55.8 (1.4)	561 / 51.5 (1.7)	309 / 53.9 (2.1)	
Marital status:					0.000[d]
Have partner	6,017 / 66.4 (1.0)	462 / 54.3 (3.2)	614 / 52.0 (2.6)	273 / 47.4 (3.3)	
No partner	3,447 / 33.6 (1.0)	389 / 45.7 (3.2)	479 / 48.0 (2.6)	300 / 52.6 (3.3)	
Country of birth:					0.000[d]
US-born	7,973 / 86.9 (1.1)	587 / 76.2 (3.4)	616 / 69.8 (3.2)	388 / 78.0 (2.8)	
Foreign-born	1,821 / 13.1 (1.1)	288 / 23.8 (3.4)	508 / 30.2 (3.2)	193 /22.0 (2.8)	
Language use at home:					0.000[d]
English	7,965 / 89.0 (1.1)	549 / 75.2 (3.5)	573 / 68.4 (3.5)	373 / 74.9 (4.1)	
English/Spanish equally	354 / 1.5 (0.3)	40 / 3.2 (1.2)	66 / 4.9 (1.4)	24 / 6.0 (3.4)	
Spanish or other	1,494 / 9.5 (0.9)	289 / 21.6 (3.4)	486 / 26.7 (2.7)	188 / 19.0 (2.6)	
High PIR (≥1)	7,965 / 91.0 (0.7)	504 / 67.0 (2.8)	543 / 59.5 (3.0)	256 / 50.2 (2.9)	0.000[d]
Low PIR (<1)	1,076 / 9.0 (0.7)	300 / 33.0 (2.8)	485 / 40.5 (3.0)	298 / 49.8 (2.9)	
High school or more	7,123 / 83.2 (0.8)	441 / 62.8 (2.6)	483 / 58.4 (2.1)	260 / 55.9 (2.8)	0.000[d]
Less than high school	2,679 / 16.8 (0.8)	434 / 37.2 (2.6)	640 / 41.6 (2.1)	323 / 44.1 (2.8)	
Employed	5,612 / 67.0 (0.8)	466 / 60.6 (2.7)	563 / 56.6 (2.2)	259 / 48.8 (2.2)	0.000[d]
Unemployed	4,204 / 33.0 (0.8)	412 / 39.4 (2.7)	561 / 43.4 (2.2)	326 / 51.2 (2.2)	
Have health care coverage	8,267 / 85.6 (0.7)	598 / 68.2 (2.4)	613 / 56.3 (1.8)	352 / 61.2 (2.8)	0.000[d]
No health care coverage	1,534 / 14.4 (0.7)	277 / 31.8 (2.4)	509 / 43.7 (1.8)	233 / 38.8 (2.8)	
Participate in FSP	366 / 7.6 (0.7)	132 / 32.5 (3.2)	168 / 31.8 (2.4)	142 / 42.6 (3.9)	0.000[d]
No participation in FSP	3,241 / 92.4 (0.7)	299 / 67.5 (3.2)	384 / 68.2 (2.4)	184 / 57.4 (3.9)	

[a] Analytical sample size is unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each food security category.

[c] Refers to general linear model with Bonferroni adjustment, not adjusted for other variables. [d] Refers to χ^2 test.

FS: Food security; FSP: Food Stamp Program; PIR: poverty income ratio; SE: standard error; US: United States;

Obesity, lifestyle, and other T2D risk factor characteristics by food security status

T2D prevalence rates were 7.8%, 10.4%, 7.8%, and 13.9% for individuals with high, marginal, low, and very low food security (respectively) at the household level. As shown in Table 5, participants from food insecure households appeared to have lower rates of overweight status but higher rates of obesity in comparison to those with high food security ($p<0.05$). Prevalence of obesity was the highest among individuals from households with marginal food security. WC was not significantly different by the food security status. Participants with household food insecurity were more likely to be sedentary, smokers, and nondrinkers ($p<0.05$).

The mean energy intake was the highest among those with low food security ($p=0.061$). There were statistically significant differences in protein, carbohydrate, and fat intakes (as % of energy) by the food security status ($p<0.05$), but in practical terms, the intake differences were small. There were no statistically significant differences in fiber and cholesterol intakes by food security status.

Table 5. Obesity, lifestyle, and other type 2 diabetes risk factor characteristics by household food security status among adults, 20-84 years, in the NHANES 1999-2004

	High FS	Marginal FS	Low FS	Very low FS	P value
	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	n[a] / % or mean (SE)[b]	
BMI, mean	9,536 / 28.0(0.1)	845 / 29.1 (0.3)	1086 / 28.6 (0.3)	562 / 28.8 (0.5)	0.003[c]
BMI, %:					0.000[d]
Underweight	153 / 1.8(0.2)	8 / 1.2 (0.4)	19 / 2.8 (0.7)	13 / 3.5 (1.1)	
Normal	2,922 / 33.2(0.8)	231 / 27.3 (1.9)	311 / 31.9 (2.2)	161 / 28.8 (2.1)	
Overweight	3,460 / 35.2 (0.7)	295 / 33.4 (2.0)	367 / 28.9 (1.9)	195 / 32.8 (2.5)	
Obese	3,001 / 29.8 (0.7)	311 / 38.1 (2.2)	389 / 36.3 (1.8)	193 / 34.9 (3.0)	
WC (cm), mean	9,385 / 96.3 (0.3)	823 / 97.5 (0.9)	1,070 / 96.2 (0.9)	558 / 97.6 (1.2)	0.513[c]
WC, %: Normal	4,537 / 51.1 (1.0)	378 / 46.6 (2.3)	518 / 51.7 (2.4)	268 / 48.0 (2.3)	0.224[d]
High	4,848 / 48.9 (1.0)	445 / 53.4 (2.3)	552 / 48.3 (2.4)	290 / 52.0 (2.3)	
LTPA, %:					0.000[d]
Active	5,694 / 65.4 (1.0)	406 / 51.9 (2.8)	485 / 50.1 (2.3)	244 / 47.8 (2.8)	
Sedentary	4,123 / 34.6 (1.0)	472 / 48.1 (2.8)	640 / 49.9 (2.3)	341 / 52.2 (2.8)	
Nonsmoker	7,778 / 77.1 (0.7)	599 / 63.7 (2.4)	762 / 62.1 (2.1)	358 / 54.9 (2.8)	0.000[d]
Smoker	2,029 / 22.9 (0.7)	277 / 36.3 (2.4)	361 / 37.9 (2.1)	227 / 45.1 (2.8)	
Nondrinker	2,766 / 27.3 (1.5)	304 / 34.5 (2.2)	325 / 29.0 (2.2)	183 / 33.2 (2.2)	0.005[d]
Drinker	6,330 / 72.7 (1.5)	504 / 65.5 (2.2)	689 / 71.0 (2.2)	354 / 66.8 (2.2)	
Energy intake (kcal/d)	9,314 / 2,212.8 (13.3)	834 / 2,178.1 (49.1)	1,076 / 2,337.0 (49.2)	545 / 2,177.6 (63.7)	0.061[c]
Energy intake (kcal/d)					0.000[d]
1st quartile	2,253 / 1,064.2 (8.7)	236 / 1,056.2 (16.8)	299 / 1,059.5 (22.3)	176 / 993.8 (30.1)	
2nd quartile	2,374 / 1,663.1 (3.6)	210 / 1,679.2 (10.9)	250 / 1,662.5 (15.5)	98 / 1,638.2 (17.5)	
3rd quartile	2,383 / 2,240.1 (4.4)	189 / 2,221.8 (21.7)	241 / 2,252.6 (14.9)	132 / 2,227.1 (18.1)	
4th quartile	2,304 / 3,463.5 (23.0)	199 / 3,607.7 (68.4)	286 / 3,693.7 (70.5)	139 / 3,569.2 (106.4)	
Protein intake (% kcal/d)	9,313 / 15.3 (0.1)	834 / 15.6 (0.3)	1,076 / 14.7 (0.2)	544 / 15.0 (0.4)	0.037[c]
Carbohydrate intake (% kcal/d)	9,313 / 49.7 (0.2)	834 / 50.3 (0.5)	1,076 / 51.6 (0.5)	544 / 50.6 (0.8)	0.001[c]
Total fat intake (% kcal/d)	9,313 / 33.5 (0.2)	834 / 33.0 (0.4)	1,076 / 32.0 (0.4)	544 / 31.8 (0.6)	0.002[c]
Fiber, %:					0.161[d]
≥14g/1000kcal/d	868 / 7.5 (0.3)	62 / 4.6 (1.0)	100 / 6.3 (1.5)	60 / 6.9 (1.1)	
<14g/1000kcal/d	8,445 / 92.5 (0.3)	772 / 95.4 (1.0)	976 / 93.7 (1.5)	484 / 93.1 (1.1)	
Cholesterol, %:					0.371[d]
<300mg/d	6,095 / 65.2 (0.7)	509 / 61.8 (1.9)	667 / 64.2 (2.1)	373 / 67.3 (2.7)	
≥300mg/d	3,219 / 34.8 (0.7)	325 / 38.2 (1.9)	409 / 35.8 (2.1)	172 / 32.7 (2.7)	
No comorbidities	8,784 / 92.8 (0.4)	769 / 90.3 (1.7)	1,008 / 90.9 (1.2)	508 / 90.0 (1.3)	0.046[d]
Have comorbidities	990 / 7.2 (0.4)	103 / 9.7 (1.7)	111 / 9.1 (1.2)	71 / 10.0 (1.3)	
Family history DM					0.001[d]
No	4,881 / 51.0 (0.9)	388 / 43.8 (2.4)	531 / 45.2 (2.5)	281 / 45.0 (2.7)	
Yes	4,731 / 49.0 (0.9)	472 / 56.2 (2.4)	570 / 54.8 (2.5)	287 / 55.0 (2.7)	

[a] Analytical sample size was unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each food security category.

[c] Refers to general linear model with Bonferroni adjustment, not adjusted for other variables.

[d] Refers to χ^2 test.

BMI: Body mass index; DM: diabetes mellitus; LTPA: leisure time physical activity; SE: standard error; WC: waist circumference.

BMI: Underweight (<18.5), normal (18.5 to 24.9), overweight (25.0 to 29.9), obese (≥30.0); WC: high (>88cm in women, >102cm in men).

4.1.4 Participant Characteristics by Race/ethnicity

Participant characteristics by race/ethnicity (Mexican American vs. non-Hispanic White) are shown in Tables 6 and 7. Based on the analytical sample, population estimates were 14.0 million (7.3%) for Mexican Americans, and 138.0 million (71.4%) for non-Hispanic Whites.

Food security, SES, acculturation, and demographic characteristics by race/ethnicity

On average, Mexican Americans were younger than non-Hispanic Whites ($p<0.001$) (Table 6). They were more likely to be less acculturated (foreign-born, and speaking mostly or all Spanish/other languages at home) and have a low SES as indicated by PIR, education, and health care coverage ($p<0.000$). However, they were more likely to be employed compared to non-Hispanic Whites ($p=0.007$). Food security rates were lower for Mexican Americans in comparison to non-Hispanic Whites ($p<0.001$).

Obesity, lifestyle, and other T2D risk factor characteristics by race/ethnicity

Mexican Americans were more likely to have greater BMI and WC, and to be sedentary in comparison to non-Hispanic Whites ($p<0.05$, Table7).

Table 6. Food security, socioeconomic status, acculturation, and demographic characteristics by race/ethnicity among Mexican Americans and non-Hispanic Whites, 20-84 years, in the NHANES 1999-2004[a]

	Mexican Americans (n=2,955)		Non-Hispanic Whites (n=6,363)		P value
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
Age, mean	2,955	38.3 (0.7)	6,363	47.5 (0.3)	0.000[c]
Age, %: 20-39yr	1,078	60.1 (2.1)	1,869	34.9 (0.9)	0.000[d]
40-59yr	884	30.1 (1.3)	2,002	40.5 (0.8)	
60-84yr	993	9.8 (1.2)	2,492	24.6 (0.7)	
Male	1,502	54.6 (1.0)	3,231	49.1 (0.5)	0.000[d]
Female	1,453	45.4 (1.0)	3,132	50.9 (0.5)	
Marital status: Have partner	1,955	67.6 (1.4)	4,083	68.1 (0.8)	0.763[d]
No partner	886	32.4 (1.4)	2,090	31.9 (0.8)	
Country of birth: US-born	1,254	40.3 (3.2)	6,016	95.0 (0.6)	0.000[d]
Foreign-born	1,699	59.7 (3.2)	336	5.0 (0.6)	
Language use at home:					0.000[d]
English	845	31.0 (1.6)	6142	96.7 (0.5)	
English/Spanish equally	405	12.5 (1.6)	5	0.1 (0.1)	
Spanish or other	1702	56.5 (2.4)	214	3.3 (0.5)	
High FS	1,829	62.5 (1.9)	5,428	89.6 (0.7)	0.000[d]
Marginal FS	298	10.7 (1.1)	231	3.4 (0.3)	
Low FS	532	20.5 (1.6)	283	4.4 (0.4)	
Very low FS	173	6.3 (0.8)	179	2.6 (0.3)	
High PIR (≥1)	1,915	72.8 (1.7)	5,268	90.8 (0.8)	0.000[d]
Low PIR (<1)	742	27.2 (1.7)	624	9.2 (0.8)	
Education: High school or more	1,107	45.4 (1.6)	5,287	86.4 (1.0)	0.000[d]
Less than high school	1,844	54.6 (1.6)	1,069	13.6 (1.0)	
Employed	1,686	70.9 (1.5)	3,486	65.4 (0.9)	0.007[d]
Unemployed	1,267	29.1 (1.5)	2,875	34.6 (0.9)	
Have health care coverage	1,841	53.2 (2.1)	5,562	86.9 (0.7)	0.000[d]
No health care coverage	1,072	46.8 (2.1)	739	13.1 (0.7)	
Participate in FSP	147	12.0 (1.7)	264	9.4 (1.0)	0.149[d]
No participation in FSP	893	88.0 (1.7)	2,170	90.6 (1.0)	

[a] Analytical sample size was unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each race/ethnicity category.

[c] Refers to independent samples t-test.

[d] Refers to $\chi 2$ test.

FS: Food security; FSP: Food Stamp Program; PIR: poverty income ratio; SE: standard error; US: United States.

Although there seemed to be a statistically significant difference in protein and carbohydrate intakes as percentage of calories ($p<0.05$), the differences were small in a practical sense. Mexican Americans were more likely to have greater intakes of fiber and cholesterol, and a lower intake of total fat than non-Hispanic Whites ($p<0.001$).

Table 7. Obesity, lifestyle, and other type 2 diabetes risk factor characteristics by race/ethnicity among Mexican Americans and non-Hispanic Whites, 20-84 years, in the NHANES 1999-2004

	Mexican Americans (n=2955)		Non-Hispanic Whites (n=6363)		P value
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
BMI, mean	2,876	28.4 (0.2)	6,179	27.9 (0.1)	0.018[c]
BMI, %: Underweight (<18.5)	17	0.6 (0.2)	120	2.1 (0.2)	0.001[d]
Normal (18.5 to 24.9)	747	28.3 (1.7)	2,044	33.7 (0.9)	
Overweight (25.0 to 29.9)	1,148	38.4 (0.8)	2,176	34.1 (0.7)	
Obese (≥30.0)	964	32.7 (1.5)	1,839	30.2 (0.8)	
WC (cm), mean	2,831	95.5 (0.6)	6,096	96.8 (0.3)	0.039[c]
WC, %: Normal	1,358	54.2 (1.8)	2,914	50.0 (1.1)	0.071[d]
High	1,473	45.8 (1.8)	3,182	50.0 (1.1)	
LTPA, %: Active	1,300	48.9 (1.7)	4,042	67.1 (1.1)	0.000[d]
Sedentary	1,653	51.1 (1.7)	2,320	32.9 (1.1)	
Nonsmoker	2,365	76.6 (1.0)	4,865	74.8 (0.9)	0.105[d]
Smoker	585	23.4 (1.0)	1,490	25.2 (0.9)	
Nondrinker	874	28.3 (1.2)	1,598	25.0 (1.7)	0.055[d]
Drinker	1,828	71.7 (1.2)	4,397	75.0 (1.7)	
Energy intake (kcal/d)	2,793	2,260.9 (25.9)	6,091	2,252.3 (14.6)	0.744[c]
Energy intake (kcal/d): 1st quartile	745	1,046.7 (11.9)	1,313	1,078.6 (9.4)	0.608[d]
2nd quartile	711	1,670.9 (7.9)	1,535	1,664.8 (3.8)	
3rd quartile	691	2,239.0 (7.3)	1,609	2,241.3 (5.5)	
4th quartile	646	3,489.7 (35.9)	1,634	3,480.9 (20.9)	
Protein intake (% kcal/d)	2,793	15.5 (0.1)	6,091	15.2 (0.1)	0.023[c]
Carbohydrate intake (% kcal/d)	2,793	51.4 (0.5)	6,091	49.3 (0.2)	0.000[c]
Total fat intake (% kcal/d)	2,793	31.6 (0.4)	6,091	34.0 (0.2)	0.000[c]
Fiber, %: ≥14g/1000kcal/d	409	10.9 (0.8)	481	6.9 (0.4)	0.000[d]
<14g/1000kcal/d	2,384	89.1 (0.8)	5,610	93.1 (0.4)	
Cholesterol, %:<300mg/d	1,703	58.7 (1.5)	4,072	65.5 (0.6)	0.000[d]
≥300mg/d	1,090	41.3 (1.5)	2,019	34.5 (0.6)	
No comorbidities	2,697	96.3 (0.5)	5,575	91.7 (0.5)	0.000[d]
Have comorbidities	240	3.7 (0.5)	760	8.3 (0.5)	
Family history DM: No	1,407	48.1 (1.4)	3,275	51.2 (1.1)	0.122[d]
Yes	1,497	51.9 (1.4)	2,940	48.8 (1.1)	

[a] Analytical sample size was unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each race/ethnicity category.

[c] Refers to independent samples t-test. [d] Refers to $\chi 2$ test.

BMI: Body mass index; DM: diabetes mellitus; LTPA: leisure time physical activity; SE: standard error; WC: waist circumference.

BMI: Underweight (<18.5), normal (18.5 to 24.9), overweight (25.0 to 29.9), obese (≥30.0); WC: high (>88cm in women, >102cm in men).

4.1.5 Participant Characteristics by Acculturation Status

Country of birth and language spoken at home, which were used as the proxy measures for acculturation status were significantly and highly correlated with one another (r=0.77, p=0.000). As seen in Tables 8 and 9, both variables indicated generally similar participant characteristics with only a few exceptions: country of birth was a better predictor of T2D status, but language use at home was a better predictor for differences in marital status, FSP participation, and cholesterol intake (p<0.05).

Less (vs. more) acculturated individuals (e.g., those who were foreign-born or spoke mostly or only Spanish/other at home), were more likely to be male, younger, food insecure (at the household level), and to have a low SES, as determined by PIR, education, and health care coverage (p<0.000). They appeared to have a lower BMI and WC, and they were more likely to be sedentary and nondrinkers (p<0.05). They had higher intakes of protein, carbohydrate, and fiber, and lower intake of total fat (p<0.000).

Individuals who spoke English/Spanish equally appeared to have several characteristics that showed intermediate values in comparison to those of the English-speaking and Spanish/other language-speaking groups. These characteristics included age, food insecurity, PIR, education, health care coverage, physical activity, and intakes of protein, carbohydrate, fat, and fiber. Those who spoke English/Spanish equally had the highest BMI, WC, and cholesterol intake. This language category was available only for Mexican Americans, and overall, it appeared to have characteristics that were not similar to the other two language categories.

Table 8. Food security, socioeconomic status, and demographic characteristics by country of birth and language use at home among Mexican Americans and non-Hispanic Whites, 20-84 years, in the NHANES 1999-2004

	Country of birth				P value	Language use at home						P value
	US-born		Foreign-born			English		English/Spanish equally		Spanish or other		
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]		n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
Age, mean	7,270	47.2	2,035	40.8	0.000[c]	6,987	47.3 (0.3)	410	41.1 (1.4)	1,916	39.4 (0.7)	0.000[e]
Male	3,650	49.0 (0.5)	1,076	55.2 (1.2)	0.000[d]	3,525	49.2 (0.5)	179	45.8 (3.0)	1,028	55.1 (1.5)	0.000[d]
Female	3,620	51.0 (0.5)	959	44.8 (1.2)		3,462	50.8 (0.5)	231	54.2 (3.0)	888	44.9 (1.5)	
Marital status:					0.115[d]							0.015[d]
Have partner	2,395	32.2 (0.8)	580	29.7 (1.5)		2,319	32.2 (0.8)	126	37.4 (3.6)	529	28.0 (1.7)	
No partner	4,634	67.8 (0.8)	1,395	70.3 (1.5)		4,460	67.8 (0.8)	257	62.6 (3.6)	1,320	72.0 (1.7)	
High FS	6,049	89.0 (0.6)	1,197	69.6 (2.2)	0.000[d]	5,877	89.3 (0.6)	299	74.8 (3.3)	1,078	64.8 (2.6)	0.000[d]
Marginal FS	324	3.6 (0.3)	205	8.3 (1.1)		285	3.5 (0.3)	27	5.7 (1.0)	217	9.8 (1.3)	
Low FS	388	4.6 (0.4)	426	17.2 (1.6)		335	4.5 (0.4)	54	17.0 (2.9)	425	19.7 (1.9)	
Very low FS	219	2.7 (0.3)	133	4.9 (0.7)		204	2.7 (0.3)	11	2.5 (0.6)	137	5.7 (0.7)	
High PIR (≥1)	5,935	90.7 (0.7)	1,241	75.9 (2.0)	0.000[d]	5,811	91.0 (0.8)	290	76.4 (2.6)	1,080	69.3 (2.1)	0.000[d]
Low PIR (<1)	784	9.3 (0.7)	580	24.1 (2.0)		670	9.0 (0.8)	83	23.6 (2.6)	612	30.7 (2.1)	
High school or more	5,703	85.6 (0.9)	685	55.8 (2.0)	0.000[d]	5,711	86.2 (0.9)	174	55.4 (3.6)	509	46.7 (2.1)	0.000[d]
Less than high school	1,560	14.4 (0.9)	1,348	44.2 (2.0)		1,272	13.8 (0.9)	234	44.6 (3.6)	1,405	53.3 (2.1)	
Employed	3,986	65.7 (0.8)	1,184	67.6 (1.3)	0.259[d]	3,926	65.8 (0.9)	204	64.0 (3.2)	1,042	66.5 (1.4)	0.798[d]
Unemployed	3,283	34.3 (0.8)	850	32.4 (1.3)		3,061	34.2 (0.9)	206	36.0 (3.2)	873	33.5 (1.4)	
Have health care coverage	6,265	86.5 (0.7)	1,127	59.6 (2.4)	0.000[d]	6,061	86.8 (0.7)	315	67.2 (2.4)	1,024	52.9 (2.7)	0.000[d]
No health care coverage	930	13.5 (0.7)	880	40.4 (2.4)		856	13.2 (0.7)	90	32.8 (2.4)	864	47.1 (2.7)	
Participate in FSP	318	9.6 (1.0)	91	9.5 (1.4)	0.947[d]	273	9.1 (1.0)	31	19.1 (3.4)	107	13.7 (2.1)	0.004[d]
No participation in FSP	2,422	90.4 (1.0)	640	90.5 (1.4)		2,319	90.9 (1.0)	140	80.9 (3.4)	603	86.3 (2.1)	

[a] Analytical sample size was unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each race/ethnicity category.

[c] Refers to independent samples t-test. [d] Refers to $\chi 2$ test.

[e] Refers to general linear model, Bonferroni adjustment, not adjusted for other variables.

FS: Food security; FSP: Food Stamp Program; PIR: poverty income ratio; SE: standard error; US: United States.

Table 9. Obesity, lifestyle, and other type 2 diabetes risk factor characteristics by country of birth and language use at home among Mexican Americans and non-Hispanic Whites, 20-84 years, in the NHANES 1999-2004

	Country of birth				P value	Language use at home						P value
	US-born		Foreign-born			English		English/Spanish equally		Spanish or other		
	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]		n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	n[a]	% or mean (SE)[b]	
No diabetes	6,488	92.5 (0.3)	1,791	94.1 (0.6)	0.042[c]	6,293	92.6 (0.3)	353	92.5 (1.1)	1,637	93.3 (0.7)	0.553[c]
Have T2D	782	7.5 (0.3)	244	5.9 (0.6)		694	7.4 (0.3)	57	7.5 (1.1)	279	6.7 (0.7)	
BMI, mean	7,059	28.1 (0.1)	1,983	27.3 (0.2)	0.000[d]	6,793	28.0 (0.1)	398	29.2 (0.5)	1,861	27.6 (0.2)	0.035[e]
BMI, %: Underweight (<18.5)	118	2.0 (0.2)	19	1.5 (0.5)	0.019[c]	120	2.0 (0.2)	1	0.2 (0.2)	16	1.3 (0.5)	0.008[c]
Normal (18.5-24.9)	2,206	32.9 (0.9)	580	35.6 (1.7)		2,191	33.3 (0.8)	93	23.7 (2.7)	505	32.6 (1.7)	
Overweight (25.0-29.9)	2,504	34.2 (0.7)	816	37.6 (1.6)		2,386	34.1 (0.7)	151	38.4 (3.7)	786	38.9 (1.4)	
Obese (≥30.0)	2,231	30.9 (0.8)	568	25.3 (1.4)		2,096	30.6 (0.8)	153	37.7 (4.3)	554	27.1 (1.5)	
WC (cm), mean	6,967	97.0 (0.3)	1,947	93.6 (0.5)	0.000[d]	6,709	96.9 (0.3)	390	97.8 (1.1)	1,824	94.0 (0.6)	0.000[e]
WC, %: Normal	3,212	49.2 (1.0)	1,053	61.2 (1.6)	0.000[c]	3,159	49.6 (1.0)	149	42.1 (3.4)	961	60.7 (1.9)	0.000[c]
High	3,755	50.8 (1.0)	894	38.8 (1.6)		3,550	50.4 (1.0)	241	57.9 (3.4)	863	39.3 (1.9)	
LTPA, %: Active	4,488	66.8 (1.1)	849	53.6 (1.9)	0.000[c]	4,428	67.3 (1.1)	185	52.7 (4.1)	729	47.0 (1.8)	0.000[c]
Sedentary	2,782	33.2 (1.1)	1,185	46.4 (1.9)		2,559	32.7 (1.1)	225	47.3 (4.1)	1,186	53.0 (1.8)	
Nonsmoker	5,599	74.9 (0.9)	1,621	75.3 (1.2)	0.759[c]	5,387	75.0 (0.9)	320	76.6 (3.6)	1,522	74.4 (1.5)	0.855[c]
Smoker	1,664	25.1 (0.9)	410	24.7 (1.2)		1,594	25.0 (0.9)	90	23.4 (3.6)	391	25.6 (1.5)	
Nondrinker	1,857	24.9 (1.6)	610	28.7 (1.8)	0.027[c]	1,747	24.6 (1.7)	129	31.2 (3.1)	593	31.8 (2.1)	0.001[c]
Drinker	4,999	75.1 (1.6)	1,219	71.3 (1.8)		4,865	75.4 (1.7)	241	68.8 (3.1)	1,118	68.2 (2.1)	
Energy intake (kcal/d)	6,963	2258.9 (14.3)	1,909	2202.9 (34.5)	0.112[d]	6,699	2259.3 (14.9)	381	2285.1 (72.3)	1,799	2174.4 (37.9)	0.086[e]
Protein intake (% kcal/d)	6,963	15.1 (0.1)	1,909	15.8 (0.2)	0.000[d]	6,699	15.1 (0.1)	381	15.5 (0.2)	1,799	16.1 (0.2)	0.000[e]
Carbohydrate intake (% kcal/d)	6,963	49.2 (0.2)	1,909	52.0 (0.5)	0.000[d]	6,699	49.2 (0.2)	381	50.5 (0.8)	1,799	52.1 (0.5)	0.000[e]
Total fat intake (% kcal/d)	6,963	34.1 (0.2)	1,909	30.6 (0.3)	0.000[d]	6,699	34.1 (0.2)	381	32.1 (0.5)	1,799	30.5 (0.4)	0.000[e]
Fiber, %: ≥14g/1000kcal/d	550	6.6 (0.4)	338	13.9 (1.1)	0.000[c]	530	6.8 (0.4)	44	8.2 (1.7)	314	12.3 (0.9)	0.000[c]
<14g/1000kcal/d	6,413	93.4 (0.4)	1,571	86.1 (1.1)		6,169	93.2 (0.4)	337	91.8 (1.7)	1,485	87.7 (0.9)	
Cholesterol, %: <300mg/d	4,552	65.1 (0.7)	1,215	62.9 (1.5)	0.171[c]	4,428	65.4 (0.6)	231	57.7 (4.3)	1,112	60.6 (1.8)	0.004[c]
≥300mg/d	2,411	34.9 (0.7)	694	37.1 (1.5)		2,271	34.6 (0.6)	150	42.3 (4.3)	687	39.4 (1.8)	

[a] Analytical sample size was unweighted; total sample size for each measure may vary because of missing data.

[b] Adjusted for the complex sample design. Percentages are within each race/ethnicity category.

[c] Refers to $\chi 2$ test. [d] Refers to independent samples t-test. [e] Refers to general linear model, Bonferroni adjustment, not adjusted for other variables.

BMI: Body mass index; LTPA: leisure time physical activity; SE: standard error; T2D: type 2 diabetes; US: United States; WC: waist circumference, high (>88cm in women, >102cm in men).

4.2 Multivariate Analyses

4.2.1 Associations of Food Insecurity, Socioeconomic Status and Type 2 Diabetes

A multivariate logistic regression model was used to examine the associations between food insecurity, SES indicators, country of birth, race/ethnicity, and T2D (SES model). Findings are shown in Table 10.

Table 10. Multivariate logistic regression determinants of type 2 diabetes among adults, 20-84 years, in the NHANES 1999-2004: SES model[a]

Predictor variables	n	OR (95% CI)[b]	P value [b,c]
High FS	9,007	1.00	0.019
Marginal FS	799	1.56 (1.06-2.29)	
Low FS	1,025	1.12 (0.83-1.51)	
Very low FS	550	2.06 (1.26-3.38)	
Age: 20-39yr	3,811	1.00	0.000
40-59yr	3,667	6.20 (4.62-8.32)	
60-84yr	3,903	12.64 (9.04-17.67)	
Race/ethnicity: Mexican American	2,566	1.73 (1.34-2.23)	0.000
Non-Hispanic White	5,702	1.00	
Other	3,113	1.87 (1.57-2.23)	
Country of birth: US-born	8,860	1.00	0.160
Foreign-born	2,521	0.82 (0.62-1.09)	
Education: High school diploma or more	7,719	1.00	0.001
Less than high school	3,662	1.39 (1.16-1.67)	
Employed	6,414	1.00	0.000
Unemployed	4,967	1.70 (1.36-2.12)	
PIR by gender interaction:			0.000
Women, high PIR	4,454	1.00	
Women, low PIR	1,154	1.20 (0.92-1.56)	
Men, high PIR	4,786	1.52 (1.30-1.77)	
Men, low PIR	987	1.18 (0.80-1.74)	

[a] Hosmer and Lemeshow $\chi 2=7.707$, df=8, p=0.463, Nagelkerke $R^2=0.185$, unadjusted for the design; n=11,381.

[b] Adjusted for the study design. [c] Overall significance level for the variable.

CI: confidence interval; FS: food security; OR: odd ratio; PIR: poverty income ratio; US: United States.

Compared to the individuals from households with high food security, participants with household marginal food security and very low food security were more likely to have T2D after controlling for SES, demographic characteristics, country of birth, and race/ethnicity. The association between low food security and T2D was not statistically significant. Combining four food security categories into two (high food security, marginal/low/very low food security), or three (high food security, marginal/low food security, very low food security) categories did not significantly change the associations in this model. The original four-category food security variable was retained to be able to detect a potential nonlinear association between food security and T2D.

Among the SES indicators, less than high school education and unemployment were related to a higher likelihood of having T2D after adjusting for food security, country of birth, and demographic characteristics ($p<0.05$). There was a significant interaction between PIR and gender. High-PIR men were more likely to have T2D compared to high-PIR women, and low PIR was not significantly related to the likelihood of having T2D regardless of gender.

FSP participation, health care coverage, and marital status were excluded from this model because these variables were not significantly related to T2D in the earlier multivariate analyses. Inclusion of FSP participation in the model attenuated the associations of food security and dietary intakes of total energy, protein, carbohydrate, and fat with T2D (data not shown). However, these results would be highly biased because the rate of missing data with the FSP variable was very high (61.0%), and the NCHS guidelines stated that imputation would lead to erroneous results. Therefore, FSP was excluded from the analyses. Age was used as a categorical variable in the multivariate models solely to improve the model fit.

A preliminary multivariate model indicated that after adjusting for age alone, Mexican Americans were about 1.9 times likely to have T2D compared to non-Hispanic Whites (OR 1.86, CI 1.55-2.23, p=0.000, adjusted for sample design; Hosmer and Lemeshow χ^2=9.623 df=7, p=0.211, Nagelkerke R^2=0.164, unadjusted for sample design). As seen in Table 10, after further adjustment for SES, country of birth, and demographic characteristics, Mexican Americans were about 1.7 times more likely to have T2D (p=0.000).

Country of birth was retained as a proxy of acculturation status instead of the language measure for the multivariate analyses. The rationale for this determination was that language use at home did not have the same answer options for all racial/ethnic groups. It included only Mexican Americans in the intermediate (English/Spanish equally) category, and individuals in this middle category appeared to have different characteristics than those in the other two language categories.

Hence, combining this category with either one of the other two would not have been appropriate, as it would have resulted in sparse cells and unreliable estimates. Country of birth was not significantly related to the likelihood of T2D after adjusting for food insecurity, SES, race/ethnicity, and demographic characteristics, and replacing it with language use variable did not result in any significant changes in the model.

4.2.2 Associations of Food Insecurity, Socioeconomic Status, and Type 2 Diabetes after Adjusting for Obesity, Lifestyle Factors, and Other Risk Factors

The associations between food insecurity, SES indicators, and T2D, while controlling for likely T2D risk factors, were examined through a model shown in Table 11.

Although marginal food security was significantly related to T2D in the SES model, it was no longer significant after adjusting for other T2D risk factors and covariates. The only statistically significant association between food security and T2D was for the very low food security category. Those who fell into this category exhibited about 84% greater likelihood of having T2D when compared to the individuals from households with high food security.

Table 11. Multivariate logistic regression determinants of type 2 diabetes among adults, 20-84 years, in the NHANES 1999-2004[a]

Predictor variables	n	OR (95% CI)[b]	P value[b,c]
High FS	7,820	1.00	0.213
Marginal FS	678	1.05 (0.69-1.61)	
Low FS	873	0.89 (0.63-1.26)	
Very low FS	456	1.84 (1.02-3.31)	
Age: 20-39yr	3,216	1.00	0.000
40-59yr	3,233	4.80 (3.23-7.13)	
60-84yr	3,378	10.33 (7.27-14.68)	
Race/ethnicity: Mexican American	2,193	1.74 (1.31-2.31)	0.000
Non-Hispanic White	5,050	1.00	
Other	2,584	1.92 (1.61-2.29)	
Country of birth: US-born	7,727	1.00	0.048
Foreign-born	2,100	1.37 (1.00-1.87)	
Education: High school diploma or more	6,790	1.00	0.054
Less than high school	3,037	1.26 (1.00-1.59)	
Employed	5,609	1.00	0.007
Unemployed	4218	1.35 (1.09-1.67)	
Women, high PIR	3,878	1.00	0.005
Women, low PIR	931	1.16 (0.83-1.61)	
Men, high PIR	4,188	1.57 (1.25-1.99)	
Men, low PIR	830	1.23 (0.82-1.87)	
WC (cm)	9,827	1.05 (1.04-1.05)	0.000
LTPA: Active	5,646	1.00	0.066
Sedentary	4,181	1.18 (0.99-1.41)	
Nonsmoker	7,540	1.00	0.382
Smoker	2,287	1.10 (0.88-1.38)	
Nondrinker	2,989	1.00	0.116
Drinker	6,838	0.85 (0.69-1.04)	
Energy intake (kcal/d): 1st quartile	2,397	1.00	0.003
2nd quartile	2,421	0.79 (0.58-1.07)	
3rd quartile	2,499	0.76 (0.61-0.96)	
4th quartile	2,510	0.56 (0.40-0.78)	
Fiber intake: ≥14g/1000kcal/d	905	1.00	0.002
<14g/1000kcal/d	8922	0.60 (0.44-0.82)	
Protein intake (% of kcal/d)	9,827	1.06 (1.03-1.10)	0.000
Carbohydrate intake (% of kcal/d)	9,827	1.02 (1.00-1.04)	0.029
Total fat intake (% of kcal/d)	9,827	1.04 (1.02-1.06)	0.000
No comorbidities	8,836	1.00	0.000
Have comorbidities	991	1.92 (1.56-2.36)	
Family history of diabetes: No	4,883	1.00	0.000
Yes	4,944	3.61 (3.06-4.25)	

[a] Hosmer and Lemeshow $\chi 2$=13.911, df=8, p=0.084, Nagelkerke R Square=0.324, unadjusted for the design; n=9,827.

[b] Adjusted for the study design.

[c] Overall significance level for the variable.

CI: confidence interval; FS: food security; LTPA: leisure time physical activity; OR: odd ratio; PIR: poverty index ratio; WC: waist circumference; US: United States.

Among the SES indicators, unemployment remained significantly related to a higher likelihood of having T2D, after adjusting for food insecurity, demographic characteristics, country of birth, obesity, lifestyle, family history of diabetes and comorbidities. However, the association between education and T2D was somewhat attenuated after adjusting for likely confounders (p=0.054). The association between PIR-gender interaction and T2D remained same from the earlier SES model; men with high PIR were more likely to have T2D compared to women with high PIR.

Although foreign-born individuals appeared to be about 37% more likely to have T2D than US-born individuals, this association was not very strong (p=0.048). Mexican Americans remained more likely to have T2D compared to non-Hispanic Whites even after adjusting for other potential confounding factors.

The obesity measures, BMI and WC, were examined separately in this model because of existing multicollinearity. Although WC and BMI were both significantly associated with T2D, WC was retained for the final model because it explained a higher proportion of variation in the likelihood of having T2D (Nagelkerke R^2: 32.2% vs. 30.6%). Replacing BMI with WC did not cause any major change in the significance levels, with the exception of country of birth, which became a marginally significant determinant of T2D.

In terms of lifestyle factors, there was a tendency for sedentary individuals to more likely have T2D, after adjusting for likely confounders. Cigarette smoking and alcohol intake did not have any significant association with T2D in this model.

Intakes of energy, protein, carbohydrate, fat, and fiber were significantly related to T2D although odds ratios for protein, carbohydrate and fat intake were very small. Cholesterol intake was excluded from the multivariate analyses because it was not significantly related to T2D after adjusting for likely confounders. After controlling for total fat intake, SFA, MUFA, and PUFAs were not significantly related to T2D, and because of substantial multicollinearity these were excluded from the analyses.

Racial/ethnic differences in the associations of food insecurity, SES, and T2D after adjusting for country of birth, obesity, lifestyle, and covariates were examined by stratifying the final multivariate model by race/ethnicity, as shown in Table 12.

Table 12. Multivariate logistic regression determinants of type 2 diabetes among Mexican Americans and non-Hispanic Whites, 20-84 years, in the NHANES 1999-2004

Predictor variables	Mexican Americans[a]			Non-Hispanic Whites[b]		
	n	OR (95% CI)[c]	P value[c,d]	n	OR (95% CI)[c]	P value[c,d]
High FS	1,421	1.00	0.851	4,486	1.00	0.020
Marginal FS	237	0.99 (0.65-1.49)		182	0.88 (0.42-1.82)	
Low FS	405	1.07 (0.70-1.63)		230	0.82 (0.42-1.63)	
Very low FS	130	1.60 (0.55-4.60)		152	3.53 (1.58-7.87)	
Age: 20-39yr	774	1.00	0.000	1,478	1.00	0.000
40-59yr	683	7.88 (4.57-13.56)		1,639	4.06 (2.09-7.86)	
60-84yr	736	16.04 (9.07-28.36)		1,933	9.84 (5.39-17.95)	
US-born	954	1.00	0.926	4,800	1.00	0.566
Foreign-born	1,239	1.02 (0.67-1.56)		250	1.22 (0.62-2.39)	
Education:			0.050			0.357
High school or more	848	1.00		4,255	1.00	
Less than high school	1,345	1.35 (1.00-1.82)		795	1.18 (0.83-1.68)	
Employed	1,261	1.00	0.050	2,852	1.00	0.078
Unemployed	932	1.54 (1.00-2.38)		2,198	1.29 (0.97-1.71)	
Women, high PIR	736	1.00	0.078	2,195	1.00	0.048
Women, low PIR	317	1.57 (1.00-2.46)		275	1.31 (0.74-2.32)	
Men, high PIR	833	1.40 (0.86-2.27)		2344	1.56 (1.15-2.13)	
Men, low PIR	307	1.13 (0.48-2.62)		236	1.10 (0.51-2.37)	
WC (cm)	2,193	1.04 (1.03-1.06)	0.000	5,050	1.05 (1.05-1.06)	0.000
LTPA: Active	1,005	1.00	0.415	3,289	1.00	0.051
Sedentary	1,188	0.83 (0.53-1.30)		1,761	1.30 (1.00-1.69)	
Nonsmoker	1,764	1.00	0.008	3,868	1.00	0.556
Smoker	429	1.84 (1.18-2.87)		1,182	0.90 (0.62-1.30)	
Nondrinker	712	1.00	0.080	1,316	1.00	0.526
Drinker	1,481	0.67 (0.42-1.05)		3,734	0.91 (0.68-1.22)	
Energy intake (kcal/d):			0.014			0.011
1st quartile	582	1.00		1,077	1.00	
2nd quartile	537	1.20 (0.79-1.84)		1,263	0.67 (0.44-1.02)	
3rd quartile	553	1.15 (0.78-1.68)		1,342	0.62 (0.45-0.84)	
4th quartile	521	0.55 (0.31-0.97)		1,368	0.53 (0.35-0.80)	
Fiber intake:			0.010			0.078
≥14g/1000kcal/d	328	1.00		403	1.00	
<14g/1000kcal/d	1,865	0.56 (0.36-0.86)		4,647	0.68 (0.44-1.05)	
Protein intake (% of kcal/d)	2,193	1.14 (1.08-1.20)	0.000	5,050	1.07 (1.03-1.12)	0.002
Carbohydrate intake (% of kcal/d)	2,193	1.05 (1.01-1.09)	0.016	5,050	1.02 (1.00-1.06)	0.106
Total fat intake (% of kcal/d)	2,193	1.07 (1.03-1.12)	0.002	5,050	1.05 (1.01-1.08)	0.005
No comorbidities	2,013	1.00	0.000	4,460	1.00	0.000
Have comorbidities	180	2.80 (1.73-4.52)		590	1.99 (1.52-2.61)	
Family history of diabetes:			0.000			0.000
No	1,040	1.00		2,649	1.00	
Yes	1,153	3.80 (2.42-5.96)		2,401	3.10 (2.52-3.83)	

[a] Hosmer and Lemeshow $\chi 2$=2.292, df=8, p=0.971, Nagelkerke R Square=0.370, unadjusted for the design; n=2,193. [b] Hosmer and Lemeshow $\chi 2$=6.574, df=8, p=0.583, Nagelkerke R Square=0.302, unadjusted for the design; n=5,050.

[c] Adjusted for the study design. [d] Overall significance level for the variable.

CI: confidence interval; FS: food security; LTPA: leisure time physical activity; OR: odd ratio; PIR: poverty index ratio; WC: waist circumference; US: United States

In the race/ethnicity stratified model, the significant association between very low food security and T2D became even stronger among non-Hispanic Whites, but it was attenuated among Mexican Americans. The NCHS statistical guidelines recommend that adequate sample size should be greater than the design effect multiplied by 30 (http://www.cdc.gov/nchs/data/nhanes/nhanes3/nh3gui.pdf). According to this recommendation, the number of individuals with very low food security was adequate for a reliable estimate in both Mexican Americans (design effect of 0.447 X 30 = 13.4 people needed) and non-Hispanic Whites (design effect of 1.764 X 30 = 52.9 people needed) since there were 130 Mexican Americans and 152 non-Hispanic Whites in the very low food security category.

In terms of SES indicators, low education and unemployment remained marginally related to a greater likelihood of having T2D among Mexican Americans (p=0.05), but not among non-Hispanic Whites. Similar to the previous models, men with high-PIR were more likely to have T2D among non-Hispanic Whites; but, this association was no longer statistically significant for Mexican Americans.

The association between country of birth and T2D, which was marginal in the mixed sample, was not statistically significant in this model with race/ethnic group stratification.

WC remained significantly related to the likelihood of T2D for both racial/ethnic groups. Among the lifestyle factors, there was still a tendency for sedentary individuals to be more likely to have T2D among non-Hispanic Whites (p=0.051), but this association was not significant for Mexican Americans.

Previously nonsignificant association between cigarette smoking and T2D became significant only among Mexican Americans; smokers were about 84% more likely to have T2D than nonsmokers. Similar to the mixed model, alcohol consumption was not significantly related to T2D in any racial/ethnic group in these models.

The associations of energy, protein, and fat intakes with T2D remained statistically significant in both racial/ethnic groups. Fiber and carbohydrate intakes remained significantly associated with likelihood of having T2D among Mexican Americans, but not for non-Hispanic Whites.

Family history of diabetes, comorbidities, and age remained as significant determinants of T2D among both Mexican Americans and non-Hispanic Whites.

4.3 Summary of the Results

In summary, the results showed that marginal or very low food security was associated with a higher likelihood of T2D after adjusting for SES, race/ethnicity and demographic factors, and country of birth in a nationally representative sample from the NHANES 1999-2004. However, after further adjusting for obesity, lifestyle (physical activity, cigarette smoking, alcohol and dietary intake), family history of diabetes and comorbidities, only very low food security remained associated with a greater risk of T2D.

There were racial/ethnic differences in the associations between food insecurity, SES, and T2D. The relationship between very low food security and T2D was statistically significant among non-Hispanic Whites, but it was attenuated among Mexican Americans. In terms of SES indicators, low education and unemployment were marginally associated with a higher likelihood of T2D among Mexican Americans, but not among non-Hispanic Whites. The positive association between cigarette smoking and likelihood of T2D was statistically significant only among Mexican Americans. The associations between central adiposity (as measured by WC), dietary intake, and T2D were generally similar between the two racial/ethnic groups.

CHAPTER V. DISCUSSION

This study aimed to 1) identify whether food insecurity is related to T2D independently of SES indicators after adjusting for obesity, lifestyle factors, demographic characteristics, acculturation, and other likely confounders, (e.g., family history of diabetes and comorbidities), and to 2) examine how these associations differ between Mexican American and non-Hispanic White adults in a nationally representative sample from the NHANES 1999-2004. The results are discussed in the following sections.

5.1 Associations of Food Insecurity and Type 2 Diabetes

The current study results showed that very low food security was significantly and positively associated with the likelihood of having T2D independently of SES, obesity, lifestyle (physical activity, cigarette smoking, alcohol and dietary intake), country of birth, demographic factors, family history of diabetes and comorbidities. Existing literature examining the associations between food insecurity and T2D is scarce, but this finding strengthens a previously reported positive association between very low food security and T2D that was identified in a smaller sample of the NHANES (1999-2002) (37). It also reinforces a similar finding between food insufficiency and diabetes that was detected in a Canadian national survey (38). Unique contributions of the current study were that additional SES indicators (e.g., employment, health care coverage), acculturation, and lifestyle factors, such as cigarette smoking, alcohol intake, and dietary intake, were taken into account in the analyses, which was not done in the previously published studies.

In addition to the relationship between very low food security and T2D, this study also indicated a significant positive association between marginal food security and the likelihood of having T2D, after adjusting for SES, country of birth, and demographic factors although this association was attenuated after adjusting for other T2D risk factors. This finding is a new contribution to the current literature. In their previous report from the NHANES 1999-2002, Seligman et al. (37) used only a combined category of marginal and low food security in order to overcome inadequate sample size, which probably limited their ability to detect a significant association between marginal or low food security and T2D. The current study included a substantially larger sample size (n=12, 944 vs. 4,423, respectively), and this made it possible to examine all four levels of food security, which had not done before.

Racial differences in the association of food insecurity and T2D

When Mexican Americans and non-Hispanic Whites were examined separately, the association between very low food security and the likelihood of having T2D was stronger among non-Hispanic Whites, but it was attenuated among Mexican Americans. This is a new contribution to the relevant literature since previous studies did not examine the differences in the associations between food security and T2D between Mexican Americans and non-Hispanic Whites while controlling for an extensive number of potential confounders as was done in this study.

Potential mechanism of the link between food insecurity and T2D

A potential mechanism that may explain the positive association between food insecurity and T2D could be through dietary patterns characterized by high consumption of fats or refined grains (25) and low consumption of fresh vegetables, fruits (22, 24, 25), fish, or lean meats (24, 25). This intake pattern may be typical among individuals with food insecurity (117, 118). Although the final models in this study were adjusted for energy and macronutrient intakes to account for potential confounding, more specific food consumption patterns (e.g., intake levels for fruits, vegetables, whole grains, poultry, fish, or refined carbohydrates) could not be assessed in these analyses. Additionally, because the NHANES data were collected cross-sectionally, there is a potential for reverse causality. Having T2D may have led to healthier dietary intake patterns among participants with this disease. Further research is needed to examine the potential influence of dietary intake patterns.

Another plausible mechanism for the link between food insecurity and T2D could be cyclic eating patterns possibly stemming from monthly distribution of food assistance (SNAP or formerly known as FSP) benefits (121). Cyclic eating patterns have been positively associated with insulin resistance (133), which may result in T2D. FSP participation had a very large amount of missing data in this sample, and the NCHS recommends not imputing this variable because of data collection issues. Therefore, FSP participation could not be examined to a full extent in the current analyses, and potential effect of cyclic eating patterns on diabetes risk requires further investigation.

Another mechanism of action for the association between food insecurity and T2D could be via obesity since previous reports have indicated that food insecure individuals are more likely to be obese (Hanson, et al. 2007, Wilde, et al, 2006). This study also detected higher obesity (as measured by WC) rates among participants with marginal, low and very low (household) food security in comparison to those with high food security. However, after adjusting for likely confounders, the association between very low food security and T2D remained independent of obesity as measured by BMI or WC.

5.2 Associations of Socioeconomic Status and Type 2 Diabetes

After adjusting for other likely confounders and food insecurity, this study showed some significant relationships between various SES indicators and T2D. Employment status appeared to be a better predictor of T2D status in the multivariate model prior to the stratification by race/ethnicity, although low education was also marginally related to a higher risk of T2D. Previous research (7, 26, 148) also showed that SES indicators, such as low levels of income and education, were related to a higher likelihood of having T2D. The unique contribution of this study is the fact that several SES indicators (education, PIR, employment, health care coverage) were examined, and additional confounders such as cigarette smoking, alcohol intake, dietary intake, comorbidities, and acculturation were taken into account in the current analyses, which was missing in the current literature.

<u>Racial differences in the association of SES and T2D</u>

When the two racial/ethnic groups were examined separately, education and employment tended to be negatively related to T2D among Mexican Americans but not among non-Hispanic Whites. As this study and others (7) indicated, Mexican Americans have lower SES compared to non-Hispanic Whites, and this might be a reason for this differential finding between the two race/ethnicities. Previous research indicated that education was a stronger predictor of overweight status for Hispanics

(149) and of mortality rates for Mexican American women than their non-Hispanic counterparts (110). However, it was not known whether these associations would be similar for T2D prevalence. Hence, these results are a new contribution to the current literature by suggesting that SES indicators such as education and employment may have stronger associations with T2D for Mexican Americans than for non-Hispanic Whites.

Potential mechanism of the link between SES and T2D

One of the potential mechanisms for the link between low SES and T2D prevalence could be through access to and use of health care services. Although having health care coverage was not significantly related to T2D after adjusting for other likely confounders in the current analyses, low quality of health insurance may adversely affect health status (111), and this could not be assessed in the current study.

Other potential mechanisms may include low levels of health literacy (112), which may prevent getting the needed health information, or negative attitudes toward practicing healthy behaviors (112) among individuals with low SES. Furthermore, individuals with low SES may have poorer nutritional intakes (31), which may act as a T2D risk factor. Although this study adjusted for energy, macronutrient and fiber intakes, micronutrients and specific types of foods were not examined. Future research should look into the potential role of dietary intake patterns as well as quality measures of health care services and health literacy of individuals when examining the associations between SES and T2D.

In addition to the influence of individual SES characteristics on health status, neighborhood SES also appears to play a role in one's health. People with low SES are more likely to live in areas with low neighborhood SES that typically have limited access to healthy foods and health care facilities, and lack social support (109, 110), all of which may influence health conditions. Unfortunately, the neighborhood level SES was not measured in the NHANES 1999-2004 and could not be included in the current study.

In terms of the racial/ethnic differences, limited access to and lower quality of health care, negative attitudes toward health information (112), and lower levels of individual (7) and neighborhood SES (109, 110) among Mexican Americans might be underlying the stronger associations of SES and T2D. More research is needed to further examine these factors for their potential roles in preventing T2D.

5.3 Associations of Demographic Factors, Acculturation, and Type 2 Diabetes

This study detected a gender-specific association between poverty (PIR) and T2D. Having a higher-PIR was related to higher likelihood of T2D among men, but not among women. This finding is similar to a previous report of the Canadian

National Population Health Survey (150), which indicated that after controlling for several demographic, psychosocial, and lifestyle factors, men with higher (vs. middle) incomes were more likely to report chronic health conditions (e.g., high blood pressure, heart disease, arthritis), while these associations were not statistically significant for women. Similarly, another report (151) from the same Canadian sample indicated that having higher income was a better predictor for good self-reported health and functional health status for women than it was for men. Current study findings contribute to the previous literature by using a U.S. national sample indicating that men with high PIR may be at a greater risk for T2D compared to women with high PIR, because previous research did not examine the gender and income interaction with T2D while controlling for other T2D risk factors in a nationally representative sample in the U.S.

This gender-specific finding might be an indication of different lifestyle behaviors among men and women based on their SES. A previous study (152) among Hispanics also reported that women with higher SES consumed healthier diets, whereas men with higher SES consumed less healthy diets. Therefore, it is possible that women with higher SES might be maintaining a healthier lifestyle than men with high SES.

Lastly, this study indicated that country of birth or language use at home, as proxy measures for acculturation, were not significantly related to T2D among Mexican Americans and non-Hispanic Whites after adjusting for other likely confounders. This is inconsistent with the previous research indicating a significant association of T2D with acculturation, as measured by language use and country of birth (41, 42). However, previous study results were not adjusted for food insecurity and a variety of T2D risk factors including alcohol intake, cigarette smoking, physical activity, or dietary intake, which could modify the associations of acculturation and T2D.

5.4 Study Limitations

This study is limited by the cross-sectional nature of the survey. Thus, a causal relationship cannot be inferred. In addition, potential for reverse causality must be taken into account when interpreting these results. Having T2D may have resulted in lower SES due to worsened health conditions and decreased potential for employability. On the other hand, having T2D might have caused individuals to change their lifestyles (e.g., consume healthier diets, not smoke cigarettes, etc.) in attempts to manage T2D.

Other factors such as SNAP participation, cyclic eating patterns, consumption of specific types of foods, neighborhood-level SES, or health literacy may also influence the associations between food insecurity, SES and T2D, but these variables could not be included in the current analyses.

There were also limitations regarding some of the variables used in the analyses. The physical activity measure was limited to leisure-time activities, which might have included some household or transportation activities. However, an extensive measure of all activities (i.e., household, transportation, and occupational) could not be assessed. Absolute amounts of alcohol intake could not be assessed because of larger amount of missing data with this variable. Lastly, although language use and country of birth are commonly used proxy measures of acculturation, these may not properly account for multidimensional aspects of acculturation, but more comprehensive measures of acculturation for both racial/ethnic groups were not available in the current sample.

CHAPTER VI. CONCLUSIONS

6.1 Conclusions

This study found that very low food security and low SES are independently associated with the likelihood of having T2D in a nationally representative sample from the NHANES 1999-2004. The unique contributions of this study include the large sample size that made it possible to examine all levels of food insecurity, and a wider range of SES indicators and potential T2D risk factors than what was used in the literature previously. Furthermore, this study examined the racial differences in these associations between Mexican Americans and non-Hispanics Whites, since this was also missing in the literature. Study results suggest that food insecurity may be a stronger determinant of T2D for non-Hispanic Whites, while SES may be stronger determinant of T2D status for Mexican Americans.

6.2 Implications for Future Research and Policy

Based on the current study results, indicating that food insecurity is independently associated with the likelihood of having T2D, food insecurity should be examined and addressed as a potential risk factor for T2D. For example, brief food insecurity scales can be used as screening tools to identify individuals at risk of developing T2D.

In addition to the independent association of food insecurity and T2D, this study also indicated significant relationships between SES, obesity, dietary intake and T2D. Therefore, health professionals, educators and policy makers should develop more effective strategies to help individuals, especially those with limited resources or food insecurity, make healthier food and lifestyle choices to prevent T2D.

This study also detected racial differences in the associations of food insecurity, SES, and T2D. The results suggested that food insecurity may be a stronger determinant of T2D for non-Hispanic Whites, while SES indicators may be stronger predictors of T2D status for Mexican Americans. Hence, improving health-related knowledge, skills, and behaviors, and diabetes prevention services, and providing opportunities aiming to improve overall SES, especially among Mexican Americans, seems necessary to help resolve the health disparities.

Future research may be directed on examining the long-term effects of food insecurity, SES indicators and T2D to better understand the mechanisms of action underlying these linkages. Additionally, it is essential to identify possible confounders such as SNAP participation, cyclic eating patterns, specific food group intakes, neighborhood-level SES and social environment to further explore whether these factors that might mediate or modify the relationship between food insecurity and

T2D. Given the gender-specific differences in the association between PIR and T2D in the current analyses, future studies are needed to examine the underlying mechanisms behind this gender-PIR interaction. Lastly, longitudinal studies are needed to determine the causality of associations between food insecurity, SES, and T2D, and underlying mechanisms.

APPENDICES

Appendix A

Variables used in NHANES

Category	Variable	Label	Codes
Study design	SDMVPSU	Masked variance pseudo-PSU	
	SDMVSTRA	Masked variance pseudo-stratum	
	WTMEC2YR	Full sample 2 year MEC exam weight	
	WTMEC4YR	Full sample 4 year MEC exam weight	
Exclusion	RIDEXPRG	Pregnancy status at exam	1=Yes, positive lab pregnancy test or self-reported pregnant at exam 2=SP not pregnant at exam 3=Cannot ascertain if SP is pregnant at exam
	RIDSTATR	Interview/examination status	1= Interviewed only 2= Both Interviewed and MEC examined
Diabetes	DIQ010	Doctor told you have diabetes	1 = Yes 2 = No 3 = Borderline 7 = Refused 9 = Don't know
	LBXGLU	Glucose, plasma (mg/dL)	Continuous
	PHAFSTHR	Total length of "food fast," hours	Continuous
	PHAFSTMN	Total length of "food fast," minutes	Continuous
	DIQ050	Taking insulin now	1=Yes 2=No 7=Refused 9=Don't know
	DIQ040G DID040G	Age when first told you had diabetes	1= Enter number 2= Less than 1 year 7= Refused 9= Don't know
	DIQ040Q DID040Q	Number of years of age	Continuous
	DIQ060G DID060G	How long taking insulin	Continuous
	DIQ060Q DID060Q	Number of mos/yrs taking insulin	Continuous
Demographics	RIDAGEYR	Age at screening adjudicated	Continuous
	RIAGENDR	Gender – Adjudicated.	1=Male 2=Female
	RIDRETH1	Race/ethnicity	1=Mexican American 2=Other Hispanic 3=Non-Hispanic White 4=Non-Hispanic Black 5=Other Race – Including Multi-Racial
	DMDMARTL	Marital status	1=Married 2=Widowed 3=Divorced 4=Separated 5=Never married 6=Living with partner 77=Refused 99=Don't know

Variables used in NHANES (Continued)

Category	Variable	Label	Codes
Acculturation	DMDBORN	Country of birth	1=Born in 50 US States or Washington, DC 2=Born in Mexico 3=Born Elsewhere
	ACD010A ACD010B ACD010C	Language(s) usually spoken at home	1=English 2=Spanish 3=Other 7=Refused 9=Don't know
	ACD040	Language(s) usually spoken at home	1=Only Spanish 2=More Spanish than English 3=Both equally 4=More English than Spanish 5=Only English 7=Refused 9=Don't know
Food insecurity	HHFDSEC FSDHH	Household food security category	1 = HH full food security: 0 2 = HH marginal food security: 1-2 3 = HH low food security: 3-5/3-7 (HH with child) 4 = HH very low food security: 6-10/8-18 (HH with child)"
Socioeconomic status	INDFMPIR	CPS family PIR	Continuous 5= PIR value greater than or equal to 5.00
	DMDEDUC	Education	1=Less than high school 2=High school diploma (including GED) 3=More than high school 7=Refused 9=Don't know
	OCQ150 OCD150	Type of work done last week	1=Working at a job or business 2=With a job or business but not at work 3=Looking for work 4=Not working at a job or business 7=Refused 9=Don't know
	HID010	Covered by health insurance	
	FSD180	Authorized for fd stmps in last 12 mos	1= Yes 2= No 7= Refused 9= Don't know

Variables used in NHANES (Continued)

Category	Variable	Label	Codes
Obesity, lifestyle, and other T2D risk factors	BMXBMI	Body mass index (kg/m**2)	Continuous
	BMXWAIST	Waist circumference (cm)	Continuous
	DRXTKCAL DR1TKCAL	Energy (kcal)	Continuous
	DRXTPROT DR1TPROT	Protein (gm)	Continuous
	DRXTCARB DR1TCARB	Carbohydrate (gm)	Continuous
	DRXTTFAT DR1TTFAT	Total fat (gm)	Continuous
	DRXTSFAT DR1TSFAT	Total saturated fatty acids (gm)	Continuous
	DRXTMFAT DR1TMFAT	Total monounsaturated fatty acids (gm)	Continuous
	DRXTPFAT DR1TPFAT	Total polyunsaturated fatty acids (gm)	Continuous
	DRXTCHOL DR1TCHOL	Cholesterol (mg)	Continuous
	DRXTFIBE DR1TFIBE	Dietary fiber (gm)	Continuous
	SMQ020	Smoked at least 100 cigarettes in life	1 = Yes 2 = No 7 = Refused 9 = Don't know
	SMQ040	Do you now smoke cigarettes...	1 = Every day 2 = Some days 3 = Not at all 7 = Refused 9 = Don't know
	LBXCOT	Cotinine (ng/mL)	Continuous
	ALQ100 ALD100 ALQ101	Had at least 12 alcohol drinks/1 yr?	1=Yes 2=No 7=Refused 9=Don't know
	PAD200	Vigorous activity over past 30 days	1=Yes 2=No 3=Unable to do activity 7=Refused 9=Don't know
	PAD320	Moderate activity over past 30 days	1=Yes 2=No 3=Unable to do activity 7=Refused 9=Don't know
	PADLEVEL	Activity level	1=Moderate 2=Vigorous
	PADTIMES	# of times did activity in past 30 days	Continuous
	PADDURAT	Average duration of activity (minutes)	Continuous
	PADMETS	MET score for activity	Continuous
	MCQ250A	Blood relatives have diabetes	1= Yes 2= No 7= Refused 9= Don't know
	MCQ160B	Ever told had congestive heart failure	1= Yes 2= No 7= Refused 9= Don't know
	MCQ160D	Ever told you had angina/angina pectoris	1= Yes 2= No 7= Refused 9= Don't know
	MCQ160E	Ever told you had heart attack	1= Yes 2= No 7= Refused 9= Don't know
	MCQ160F	Ever told you had a stroke	1= Yes 2= No 7= Refused 9= Don't know

Appendix B

The USDA Household Food Security Survey Module

1. I worried whether my food would run out before I got money to buy more.
2. The food that I bought just didn't last, and I didn't have money to get more.
3. I couldn't afford to eat balanced meals.
4. I relied on only a few kinds of low-cost foods to feed my child because I was running out of money to buy food.
5. I couldn't feed my child a balanced meal, because I couldn't afford that.
6. My child was not eating enough because I just couldn't afford enough food.
7. In the last 12 months, did you ever cut the size of your meals or skip meals because there wasn't enough money for food?
8. How often did this happen?
9. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money to buy food?
10. In the last 12 months, were you ever hungry but didn't eat because you couldn't afford enough food?
11. In the last 12 months, did you lose weight because you didn't have enough money for food?
12. In the last 12 months, did you ever not eat for a whole day because there wasn't enough money for food?
13. How often did this happen?
14. In the last 12 months, did you ever cut the size of your child's meals because there wasn't enough money for food?
15. In the last 12 months, did your child ever skip meals because there wasn't enough money for food?
16. How often did this happen?
17. In the last 12 months, was your child ever hungry but you just couldn't afford more food?
18. In the last 12 months, did your child ever not eat for a whole day because there wasn't enough money for food?

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